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REMOTE SENSING AND COMPUTER-BASED VEGETATION MAPPING IN THE SAN JUAN NATIONAL FOREST, COLORADO

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Revision A

RSAL
Remote Sensing
Applications Laboratory

Lockheed
Electronics
Company, Inc.

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EXPERIMENT STATION

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ACRONYMS

ADP	automatic data processing
BCD	binary coded decimals
CCT	computer-compatible tape
CIR	color infrared
CRT	cathode ray tube
ERDC	Earth Resources Data Center
FNAM	file name
IDBUG	debug flag
I/O	input/output
ISOCLS	Interactive Self-Organizing Clustering System
IXLATE	translate flag
Landsat	land satellite
MTU	mag tape unit
NLINS	number of lines
PCC	percent of correct classification
Pixels	picture elements
QUAD	quad number
RIDS	Resource Information Display System
R2MAP	Region 2 Mapping system
RSAL	Remote Sensing Applications Laboratory
USDA	U.S. Department of Agriculture

1. INTRODUCTION

The project discussed in this report is the mapping of vegetative cover types in the San Juan National Forest using land satellite (Landsat) data images. The results derived from this effort provide input to the Region 2 Mapping (R2MAP) system which can be used for the basic planning needs of the U.S. Department of Agriculture (USDA)/Forest Service. These needs are (1) land and resource management planning, (2) resource management and project planning, and (3) resource change detection and determination.

The project was designed to develop vegetative cover-type maps into 16 categories plus snow, water, and exposed ground by classifying the appropriate Landsat data. The classification tapes that resulted from the Landsat data had to be in a format compatible with R2MAP. The product accuracy standards were set at a minimum overall cover-classification accuracy of 75 percent and a registration error of 1.0 cell (R2MAP), less than four Landsat picture elements (pixels).

It was necessary to divide the work into two phases. Phase I is the initial processing and production phase, and Phase II is the field evaluation and final production phase. Both have been completed. The project time period was from October 11, 1978, through August 15, 1979; however, contract modification authorized the new completion date of September 1, 1979.

Presented in this report are the site description followed by objectives, methods, and results of the project with a discussion of results. The technical requirements for the project are identified in the Statement of Work for the USDA/Forest Service contract number 53-82x9-8-2338 and included here as appendix A. The description of the Remote Sensing Applications Laboratory (RSAL) facility is in appendix B, and the computer program compilation for the

R2MAP offload program SJNF is in appendix C. (The offload program SJNF is derived from the name San Juan National Forest.)

2. STUDY SITE LOCATION AND DESCRIPTION

2.1 LOCATION

The study site is contained within or on the border of the San Juan National Forest. Established in 1905 and located in southwestern Colorado near the corner where Colorado, New Mexico, Arizona, and Utah meet, the San Juan National Forest is approximately 563.27 kilometers (350 highway miles) southwest of Denver, Colorado, and 402.34 kilometers (250 highway miles) northwest of Albuquerque, New Mexico. The Continental Divide, located on the southwestern slopes of the San Juan Mountains in Colorado, is the eastern boundry of the San Juan National Forest. Two vicinity maps of this National Forest are shown in figure 2-1A and 2-1B. Note that U.S. Highway 550 and U.S. Highway 84 pass through this National Forest.

The area of the San Juan National Forest is 850 477 square hectares (2 101 500 acres). Approximately 95 914 square hectares (237 000 acres) are in state, county, municipal, private, or other than National Forest Federal ownership. The area encompased by the 85 topographic 1:24 000-scale maps that cover the study site is 1 295 040 square hectares (3 200 000 acres).

2.2 DESCRIPTION[1]

2.2.1 TERRAIN

The San Juan National Forest is characterized by diversity of terrain such as flat mesas, deep canyons, rolling foothills, and steep rugged mountains. Elevations in this National Forest range from 1981.2 meters to over 4267.2 meters (6500 feet to over 14 000 feet). The La Plata Mountains, Rico Mountains, and San

[1] *San Juan National Forest Timber Management Plan 1977*, and *Unit Plans and Multiple Use Plans 1970*. USDA/Forest Service.

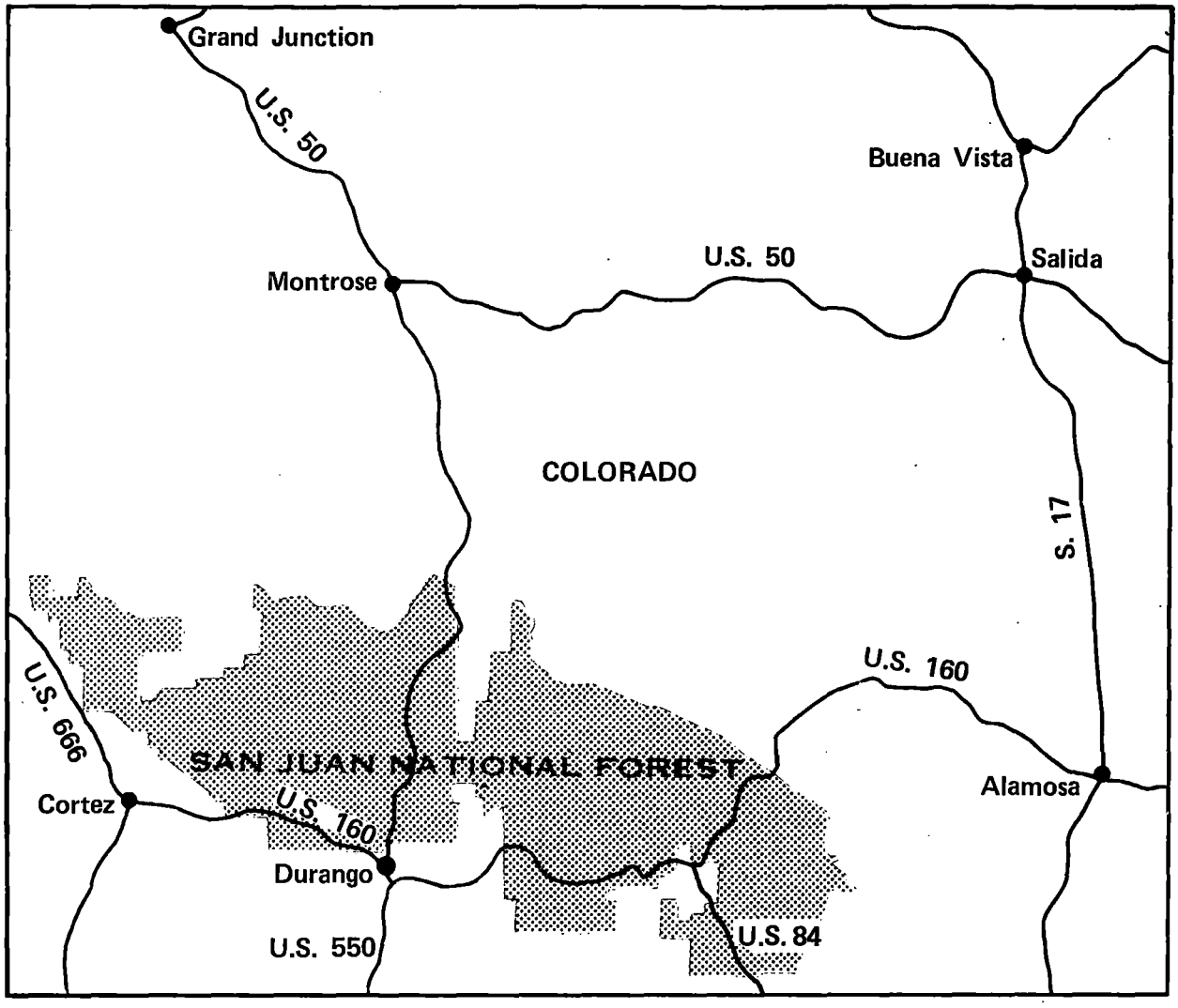


Figure 2-1A.— Vicinity map of the San Juan National Forest within Colorado.

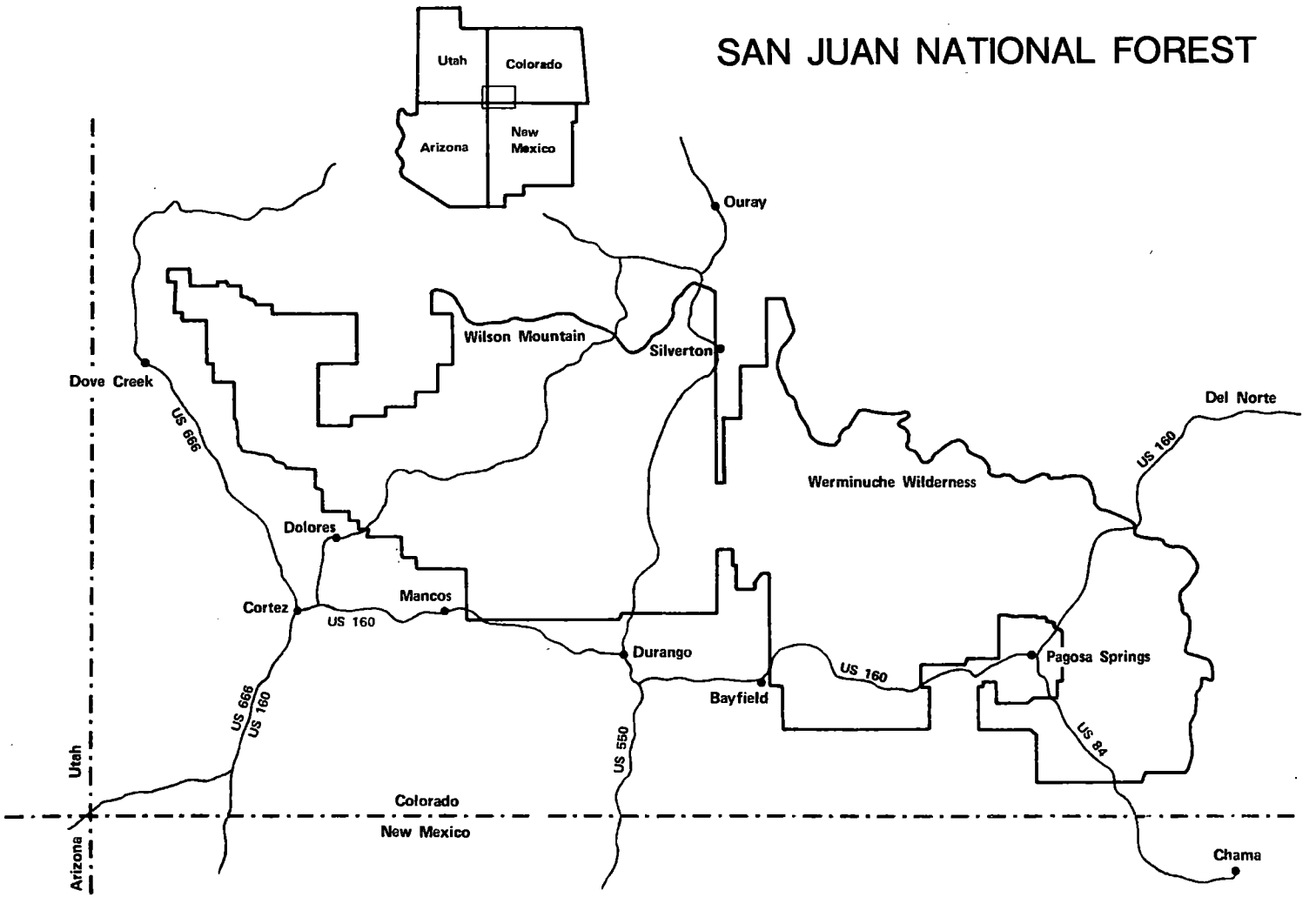


Figure 2-1B.– Detailed vicinity map of the San Juan National Forest.

Miguel (or Wilson) Mountains are isolated mountain groups in the central and western portions of the National Forest and the San Juan Mountains are in the eastern portion.

2.2.2 DRAINAGE

The San Juan River drains most of the San Juan National Forest, although the northwestern portion is in the Dolores River drainage basin. The Animas, Los Pinos, and Piedra Rivers are major tributaries of the San Juan River. Both the San Juan and Dolores River basins are part of the upper Colorado River basin.

2.2.3 GEOLOGY

The physical features of mountains, valleys, plateaus, and mesas are closely related to their underlying geology, particularly the resistant igneous formations. The eastern portion of the San Juan National Forest is comprised of layered volcanics in an area northeast of a line between Pagosa Springs and Silverton, Colorado. The central portion is comprised of sedimentaries modified by volcanic-flow rocks and intrusives overlying the granitic basement rock. Granites and schists are exposed principally southward and southeastward from Silverton and northward from Durango, Colorado. The west-central and western parts of the National Forest contain sediments and metasediments with some igneous intrusives, notably the LaPlata Mountains. The sedimentary rocks are chiefly sandstones, limestones, and shales. Landslides have shaped areas in a way that hard and massive beds, overlying soft yielding beds, have been exposed on fairly steep slopes; this particular hazard is observed in the Mancos shale formation.

2.2.4 VEGETATION

The most common vegetative zones in the San Juan National Forest are pinyon-juniper, pine-oakbrush, spruce-fir, and alpine tundra. Beginning at the lower elevations, 1981.2 meters to 2438.4 meters

(6500 feet to 8000 feet), the predominant tree species are pinyon pine, junipers, and gambel oak. These species are usually found on the rough foothills and valleys between mountain ranges. Narrowleaf cottonwood, maple, willow, and alder are found along the streams. On the upper-half of this same elevation strata, ponderosa pine and gambel oak form the main vegetation type. This tree population attains forest proportions sporadically so that openings for grass, shrubs, and wild flowers are abundant.

Moving up the mountain, the next elevation strata is 2438.4 meters to 3048 meters (8000 feet to 10 000 feet). At this level, the forest usually becomes a more dense Douglas fir-white fir-aspen forest with stream banks lined with willow and water birch.

Above 3048 meters (10 000 feet) the life pattern changes. The strata, from 3048 meters (10 000 feet) until timberline is reached at about 3505 meters (11 500 feet), is known as the Sub-alpine life zone. The soil and moisture conditions at this level are favorable for tree growth, but the snow may remain until summer, and frost is a common occurrence even in midsummer. Therefore, the forest tree species face special problems of seed production, germination, and survival. On these upper slopes, Engleman spruce and alpine fir dominate the forest. Some dense forests exist, but the normal pattern is one of small, compact tree groups with patches of grass between. Existing at this level also are large luxuriant mountain meadows covered with grass and wild flowers. Most of the mountain lakes are found here.

From the timberline up to the mountain peaks, the climate is too severe for tree growth. This level is characterized by shallow soils and harsh climate. Plant life is limited to lichens, mosses, and other low herbaceous and shrubby plants.

The vegetative zones discribed here have no sharp boundaries and tend to integrate from one to another. Several species may be found in two or more zones. Local conditions may cause such a change in climate that a particular tree may be found growing at one elevation in one part of this National Forest and at a different elevation in another part. The elevation at which a tree species may be found on mountains is determined to some extent by aspect. For the elevation strata inhabited by the various vegetative types in the San Juan National Forest see figure 2-2.

2.2.5 SOILS

Typically, soils developing from sandstones and shales support the majority of the ponderosa pine stands in the San Juan National Forest. Most of the soils developing from igneous parent materials and those developing from limestone are at higher elevations and support Englemann spruce and true fir timber stands. Most of the soils in the San Juan National Forest are fertile and productive, particularly on the low slopes in the spruce-fir timber-type area and in the gently rolling mesas underlain by sandstone in the ponderosa pine zone. Other soils vary widely ranging from shallow to deep according to the geology of an area. Large areas of rock outcrops are evident especially on alpine peaks.

2.2.6 CLIMATE

The San Juan area normally has low relative humidities, abundant sunshine, cool summers with frequent showers, heavy winter snow, and wide daily temperature fluctuations. Average annual precipitation varies from 38.1 to 152.4 centimeters (15 to 60 inches) with about 65 percent occurring as snow. Precipitation increases and temperature decreases rather uniformly with increases in elevation. Prevailing winds are from the southwest pringing most of the large storms into the area from off the southern California coast.

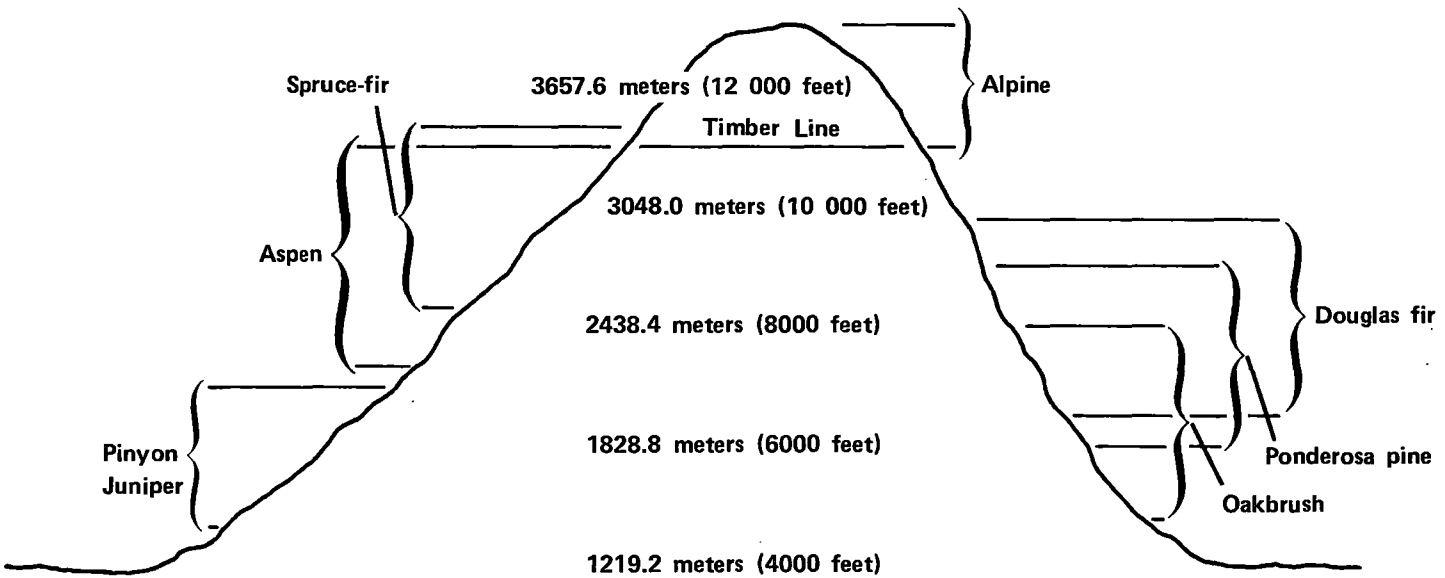


Figure 2-2.— Vegetation stratification by elevation.

2.2.7 LAKES, RESERVOIRS, AND STREAMS

Within the San Juan National Forest, there are about 1770.28 kilometers (1100 miles) of streams, 404.7 square hectares (1000 acres) of natural lakes, primarily at the higher elevations, and 1295.04 square hectares (3200 acreas) of impounded water. Although there are fewer natural lakes than in other mountain areas with glacial scouring, the 120.2-square hectare (297-acre) Emerald Lake (the second largest natural lake in Colorado) is included along with other alpine and subalpine lakes. Large impoundments include Vallecito, Lemon, and Williams Creek Reservoirs.

2.2.8 WILDLIFE

Numerous species of mammals, birds, fish, and reptiles inhabit the San Juan National Forest. Over 200 species of birds and more than 20 species of small mammals thrive. Mule deer, elk, black bears, bighorn sheep, mountain goats, mountain lions coyotes, turkeys, trout, and pike are amoung the most common wildlife. Most recent population figures indicate that there are about 24 000 mule deer, 14 000 elk, 1600 black bear, 200 bighorn sheep, 20 mountain goats, 60 mountain lions, and 1100 turkeys. Brook, native, rainbow, and brown trout are found in the streams and lakes. Northern pike is plentiful in the Vallecito Reservoir. The American peregrine falcon, an endangered species, is known to nest in this National Forest.

3. OBJECTIVES

The objectives of the San Juan National Forest project were:

a. To produce Landsat classification data tapes of the San Juan National Forest area containing 16 vegetation cover types plus snow, water, and exposed ground. Where applicable, crown closure is divided into four categories: 0 to 30 percent, 31 to 50 percent, 51 to 70 percent, and 71 to 100 percent. The classification data tapes must be compatible with the 1:24 000-scale R2MAP format covering 85 topographic maps. (R2MAP format is described in more detail in appendix A, exhibit C.)

b. To produce a separate Landsat classification data tape depicting the same classes covering the same area. This tape will be in a one-cell equals one-pixel format at an approximate scale of 1:22 500.

c. To write a formal final report that includes the procedures used for all phases of processing, the accuracy of classification and registration, a summary, and conclusions.

4. PROJECT METHODOLOGY

The major steps used in the project methodology are illustrated in figure 4-1. They are as follows:

a. Data acquisition

b. Data preprocessing

c. Feature classification

d. Registration

e. R2MAP offloading

f. Accuracy assessment

g. Reporting

Steps c, d, e, and g were done twice – once for the Phase I initial processing and production, and again for Phase II field evaluation and final production. Phase II involved a refinement of the Phase I classification and registration.

4.1 DATA ACQUISITION

Data acquisition for the project included: Landsat images, field observation, aerial photography, 1:24 000-scale topographic maps, San Juan National Forest maps, ancillary descriptive data, and R2MAP format information.

4.1.1 LANDSAT

Landsat multispectral scanner data were purchased from the U.S. Geological Survey's Earth Resources Data Center (ERDC), located in Sioux Falls, South Dakota. Geographic coordinates of the test site area were submitted to ERDC, where a search was initiated to compile a listing of all Landsat data acquired over the site. Project scientists screened the listing and selected images to serve as the classification data set. The images were selected

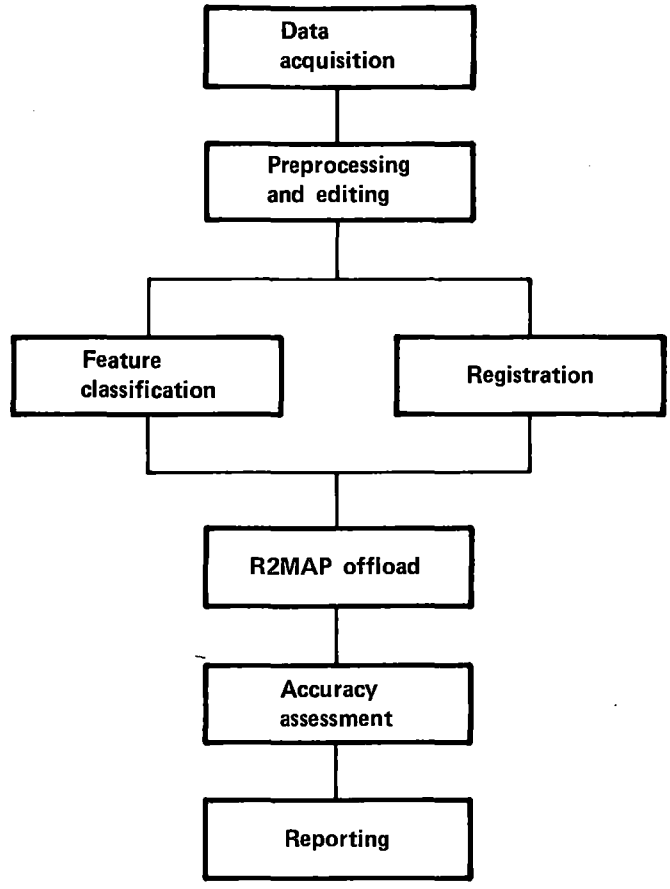


Figure 4-1.— Major steps in project methodology.

on the basis of area of coverage (entire site), timeliness (most recent possible), atmospheric conditions (minimum haze or cloud coverage), the season (late summer preferred), snow conditions (minimum snow cover), and data quality (all four channels good). It is necessary to have two images in order to obtain complete geographic coverage of the site. The site straddled two orbital paths: approximately three-fourths of the easternmost site on one image and one-fourth of the westernmost site on another image.

For the eastern portion, image 83012017085X0 (July 3, 1978) was selected. This is a high-quality Landsat-3 image with virtually no cloud cover visible. Snow cover is in the areas of highest elevation. Because the snow is located above the tree line, its probable effect would be on the classification of alpine and bare rock feature classes only, which were judged to be of minimum importance in relation to the other and more important forest classes. It was also noted that the dynamic range of the sensor was exceeded in channel 4 for some of the shadow (dark) and snow (white) areas. This was presumed to have a minimum potential impact on the classification, and the image was selected. No images having a better dynamic range in channel 4 were identified as meeting the other selection criteria.

For the western portion of the site, image 8258417060500 (August 28, 1976) was selected. This is a Landsat-2 image having nearly identical characteristics as the July 1978 image, including snow coverage and channel 4 dynamic range problems. Due to slightly different atmospheric conditions in August than in July, the image has an overall brightness that is somewhat higher than the eastern image.

The two images were ordered immediately upon award of the contract (early October 1978) and were received approximately seven weeks later (late November 1978).

4.1.2 FIELD DATA COLLECTION

Two field trips to the San Juan National Forest were necessary for the completion of the project. The first trip was for the purpose of field orientation, familiarization, and initial data collection. This trip had to be completed by October 21, 1978, in order to avoid potential access problems caused by snowfall in the mountains. A one week trip to visit a cross-section of feature types in the forest was completed on October 20, 1978. USDA/Forest Service personnel accompanied scientists from the Lockheed Electronics Company, Inc., on the trip to locate and identify features of potential importance. (As expected, the first significant snowfall of the 1978-79 winter season began on October 21, 1978.)

A second field trip was made to the forest during the week of July 16 to July 22, 1979. The purpose of this trip was to field check the aerial photography covering the quad sheets to be evaluated.

4.1.3 AERIAL PHOTOGRAPHY

During mid-October 1978, color-infrared (CIR) aerial photography of the San Juan National Forest was provided by the USDA/Forest Service. The photography was acquired during August 1978, using a large-format [22.8-centimeter by 45.7-centimeter (9-inch by 18-inch)] camera flown at approximately 19 812 meters (65 000 feet) above sea level. The resulting scale of the images was about 1:30 000. The quality of all images was excellent.

4.1.4 TOPOGRAPHIC MAPS AND ANCILLARY DATA

Topographic maps at a scale of 1:24 000, road access maps, San Juan National Forest maps, orientation maps, soils survey results, and various other reference sources were provided by USDA/Forest Service personnel during mid-October 1978. In addition, aerial

photographs having annotated examples of the 19 primary land cover feature classes along with verbal descriptions were provided by USDA/Forest Service experts. The quadrangle maps of the San Juan National Forest are shown in figure 4-2.

4.1.5 R2MAP FORMAT

Reports describing user functions of the R2MAP computer-based geographic data base system were provided by USDA/Forest Service, Region 2 personnel. A stable-base transparent data cell overlay, additional verbal details concerning the R2MAP file format, and a sample file tape were also provided. Appendix A exhibit C contains more detail on the R2MAP format.

4.2 PREPROCESSING

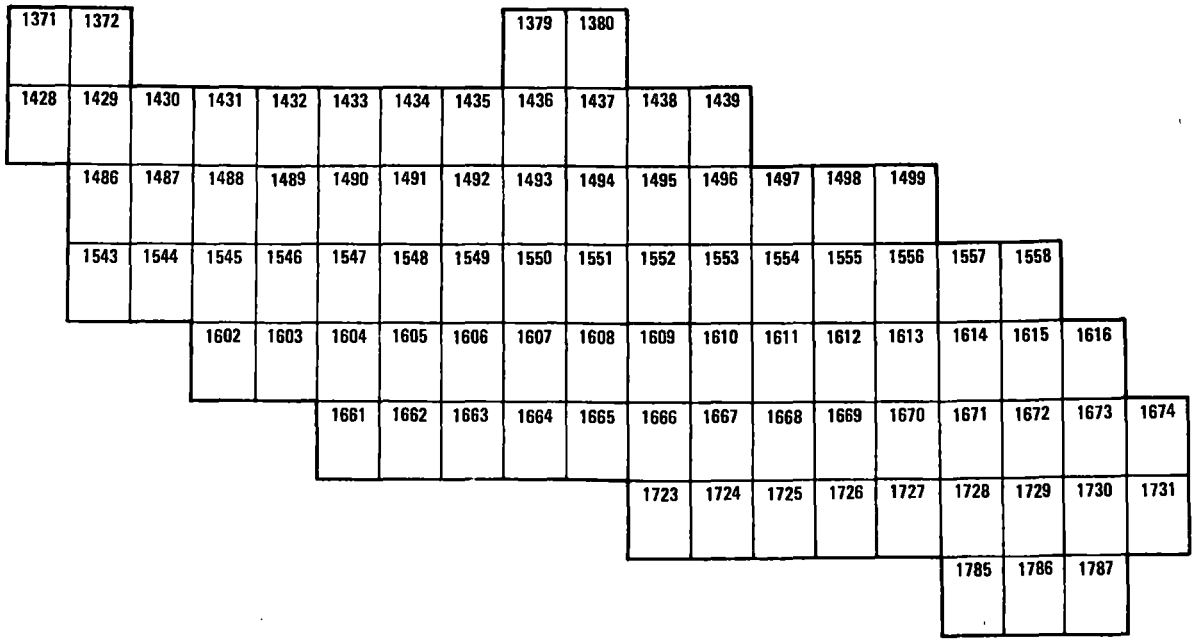
Computer-compatible tapes (CCTs) of the two Landsat images were screened for quality assurance and edited to extract portions of the images which covered the San Juan National Forest.

4.2.1 SCREENING LANDSAT IMAGES

Data screening confirmed that the Landsat images were consistent with the anticipated quality. Images of several portions of the scenes were displayed on the Vision I cathode ray tube (CRT) screen, and closely examined by project scientists for spectral response and aerial coverage. Both subjective visual evaluation and statistical analysis were used to confirm that the data quality was acceptable. This was done by using histogram frequency/response displays.

4.2.2 EDITING LANDSAT IMAGES

Editing of the Landsat images was accomplished in order to extract those portions of the images which included the San Juan National Forest area. Two test site data sets were constructed to reduce the data to two four-channel images of every pixel within the San



Legend:

1371 – Joe Davis Hill
1372 – Dawson Draw Pass
1379 – Telluride
1380 – Ironton
1428 – Secret Canyon
1429 – The Glade
1430 – Glade Mountain
1431 – South Mountain
1432 – Groundhog Reservoir
1433 – Groundhog Mountain
1434 – Dolores Peak
1435 – Mount Wilson
1436 – Ophir
1437 – Silverton
1438 – Wardsville
1439 – Idle Creek Mountain
1486 – Doe Canyon
1487 – Narraguinnep Mountain
1488 – Willow Spring
1489 – Nipple Mountain
1490 – Clyde Lake
1491 – Rico
1492 – Hermosa Peak
1493 – Engineer Mountain
1494 – Snowdon Peak
1495 – Storm King Peak
1496 – Grande Pyramid
1497 – Weminuche Pass
1498 – Little Squaw Creek
1499 – Workman Creek
1543 – Yellow Jacket
1544 – Trimble Point
1545 – Boggy Draw
1546 – Stoner
1547 – Wallace Ranch
1548 – Orphan Butte
1549 – Elk Creek
1550 – Electra Lake
1551 – Mountain View Crest
1552 – Columbine Pass
1553 – Emerald Lake
1554 – Granite Lake
1555 – Cimarrona Peak
1556 – Palomino Mountain
1557 – Spar City (southwest)
1558 – Spar City, (southeast)
1602 – Dolores East
1603 – Millwood
1604 – Rampart Hills
1605 – La Plata
1606 – Monument Hill
1607 – Hermosa
1608 – Lemon Reservoir
1609 – Vallecito Reservoir
1610 – Granite Peak
1611 – Bear Mountain
1612 – Oakbrush Ridge
1613 – Pagosa Peak
1614 – Wolf Creek Pass (northwest)
1615 – Wolf Creek Pass (northeast)
1616 – Deadwood Pass
1661 – Thompson Park
1662 – Hesperus
1663 – Durango West
1664 – Durango East
1665 – Rules Hill
1666 – Ludwig Mountain
1667 – Baldy Mountain
1668 – Devil Mountain
1669 – Chris Mountain
1670 – Pagosa Springs
1671 – Wolf Creek Pass (southwest)
1672 – Wolf Creek Pass (southeast)
1673 – Summit Peak
1674 – Platoro
1723 – Bayfield
1724 – Pargin Mountain
1725 – Chimmey Rock
1726 – Pagosa Junction (northwest)
1727 – Pagosa Junction (northeast)
1728 – Chromo (northwest)
1729 – Chromo (northeast)
1730 – Chama Peak (northwest)
1731 – Chama Peak (northeast)
1785 – Chromo (southwest)
1786 – Chromo (southeast)
1787 – Chama Peak (southwest)

Figure 4-2.– The quadrangle maps and their names in the San Juan National Forest.

Juan National Forest area to be used for final classification and mapping. Site Image 1 included approximately the eastern three-fourths of the San Juan National Forest, and Site Image 2 included approximately the western one-fourth. Overlap areas between the East and West Images were deleted from the West Image, except for a small north-south strip approximately one hundred pixels wide. The majority of the overlap area was assigned to the East Image because it was more current (July 1978) than the West Image (August 1976).

A single mosiac image that combined both images was not produced because such a map could cause possible confusion for the user. The 100-pixel-column overlap was left on the West Image for convenience in checking classification results between the two images and as an aid in avoiding the production of output maps which included a portion of the classifications from each image. The East Image was further divided into four approximately equal images (East-1, -2, -3, and -4) and the West Image into two approximately equal images (West-1 and -2). These images were created solely for convenience in processing. Figure 4-3 illustrates these divisions.

An additional data set was compiled which contained portions of both the East and West Images. This data set, called a Combined Reduced File Image, contained a systematic sample (every $5th$ row and $5th$ column pixel selected) of both images. The combined image, having slightly over 260 000 pixels of the original 1.3 million total pixels (approximate) in the East and West Images, was designed for use in statistical analysis and signature development. Its reduced size can provide significant efficiency in computer processing time during repetitive analysis processing.

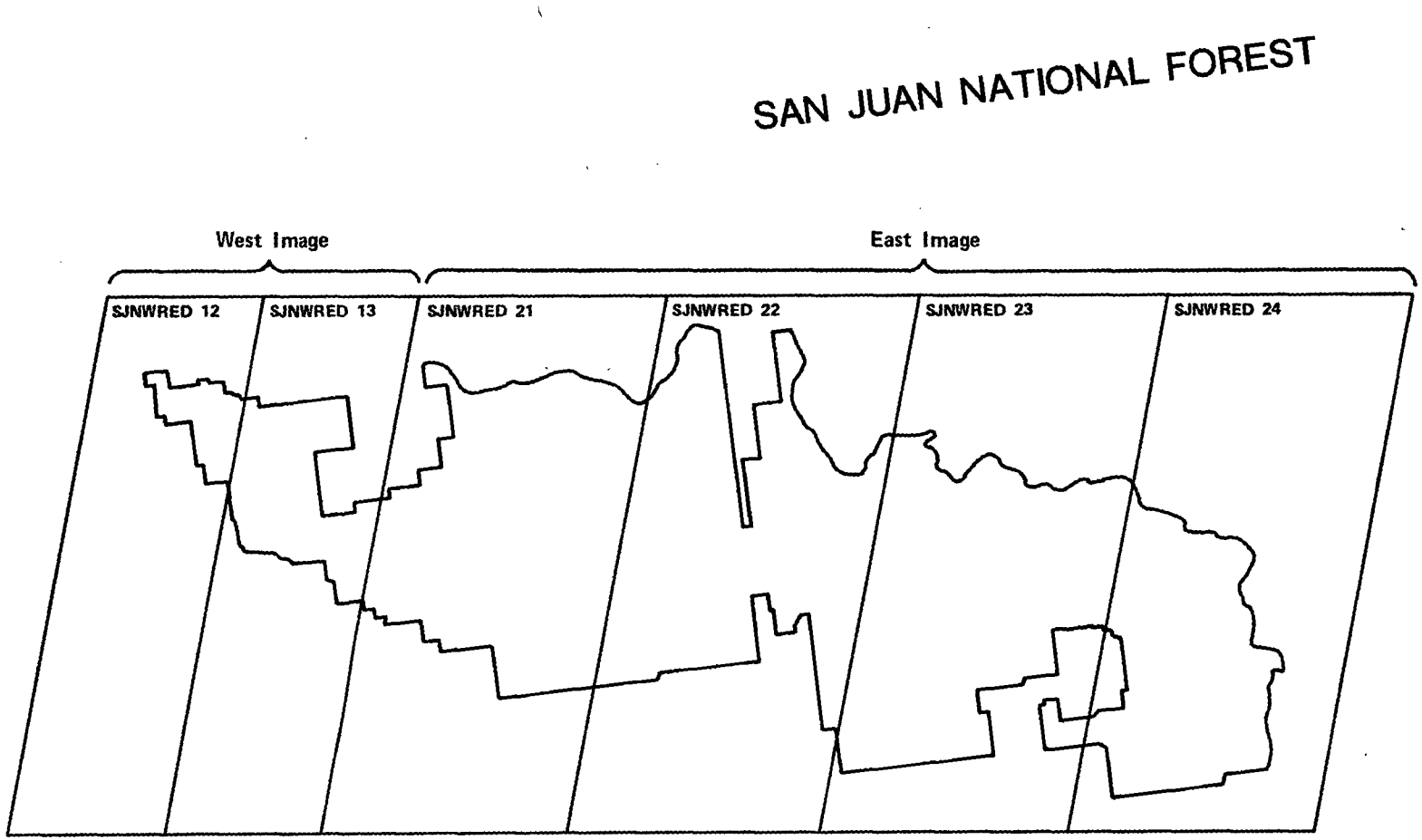


Figure 4-3.— Mosaic divisions of the data and their names for processing purposes.

4.3 FEATURE CLASSIFICATION

Feature classification was accomplished using a spectral data clustering algorithm to identify 60 spectral classes in the Landsat data. The procedures used to process the data through the clustering algorithm were designed to achieve a high information result and for efficiency in computer usage requirements.

Initially, the combined reduced image (section 4.2.2) was displayed on the interactive display device. In a systematic manner, project scientists identified a portion of the data set which was representative of spectral values for the desired classes. Using this method, 22 features were selected. These features and the spectral values for each one are listed in table 4-1. The reduced image file was then classified by assigning all image pixels to one of the 22 classes. Classes 9 and 21 were then eliminated because so few pixels in the scene fell in these classes.

The reduced image was clustered using the algorithm, Interactive Self-Organizing Clustering System (ISOCLS), and the previously identified 20 classes as starter vectors. ISOCLS is a clustering algorithm which splits, modifies, and combines classes based on the standard deviation of the mean-pixel value for each channel. After five iterations of ISOCLS processing, 60 stable spectral classes were identified. The mean-spectral values for each channel in each class were then plotted along with the standard deviations and the spectral distance between classes. A listing of the mean spectral values of the 60 classes is presented in table 4-2.

The images (East-1, -2, -3, and -4, and West-1 and -2) were classified according to the 60 classes derived from the reduced image analysis. The four resulting classification files from the East Image were then joined to produce a final classified image, and the two from the West Image were joined to produce another.

TABLE 4-1.– VALUES OF INITIAL CLASSIFICATION OF THE COMBINED REDUCED IMAGE USED AS STARTING VECTORS FOR 60-CLASS SPECTRAL CLUSTERING

Class	Mean values				Pixels classified
	Channel 1	Channel 2	Channel 3	Channel 4	
1	12.87	9.00	5.70	3.34	472
2	104.83	123.50	121.87	43.43	1 541
3	14.02	13.45	31.62	17.82	32 016
4	17.42	18.79	38.49	22.33	40 583
5	18.60	18.86	56.00	38.27	6 870
6	20.26	30.52	39.55	17.28	23 714
7	14.80	11.92	57.78	36.56	3 650
8	12.73	11.24	22.53	15.17	14 826
9	23.32	27.48	50.81	54.00	108
10	14.11	11.17	57.61	43.38	924
11	39.16	57.66	66.30	45.26	440
12	27.02	40.65	49.78	22.21	34 201
13	43.00	62.77	66.74	27.20	4 560
14	34.49	59.57	66.72	28.21	4 842
15	32.95	49.30	56.97	25.34	14 322
16	30.35	52.48	61.68	25.11	4 357
17	14.64	12.84	45.30	28.71	25 710
18	21.63	25.68	50.92	28.97	28 166
19	21.54	28.10	42.68	23.03	17 026
20	16.75	14.20	70.97	43.10	530
21	22.22	34.00	113.44	21.33	9
22	57.93	80.92	84.35	31.76	3 322
Total					262 144

TABLE 4-2.— MEAN-SPECTRAL VALUES FOR THE 60 CLASSES

Cluster	Means				Standard deviations			
	Channel 1	Channel 2	Channel 3	Channel 4	Channel 1	Channel 2	Channel 3	Channel 4
1	11.98	10.24	18.66	26.34	1.83	2.33	2.83	3.00
2	117.83	127.00	126.71	53.65	10.21	0.00	3.25	6.61
3	14.11	13.07	34.53	20.59	1.56	2.18	2.10	2.36
4	17.18	18.00	41.13	24.07	1.44	1.72	2.45	2.23
5	20.70	22.17	62.46	38.54	1.92	3.33	2.81	2.68
6	22.67	29.51	48.72	21.07	2.06	2.02	2.58	2.60
7	14.80	12.15	56.16	36.92	1.53	1.84	1.72	2.02
8	13.71	13.05	25.53	29.69	2.01	3.45	2.82	2.53
9	25.40	32.27	54.74	44.65	2.33	3.84	4.61	3.17
10	14.89	12.04	60.78	41.02	1.55	1.85	2.07	2.38
11	49.78	68.28	71.72	47.48	5.58	4.56	4.92	5.66
12	26.43	39.54	51.02	24.13	2.50	2.75	2.35	2.48
13	44.27	68.09	73.92	30.72	4.71	3.60	3.07	2.27
14	33.75	59.89	67.37	28.74	2.45	2.68	2.66	2.22
15	30.03	45.75	55.64	25.74	2.85	2.70	1.90	1.91
16	32.00	52.61	59.19	24.72	2.51	2.15	2.46	2.48
17	15.39	13.99	46.26	29.00	1.72	2.41	1.81	1.62
18	23.61	29.74	48.91	26.68	1.97	2.30	2.61	2.13
19	24.06	34.68	44.19	20.35	2.39	2.04	2.46	2.71
20	17.55	15.08	75.31	47.55	2.43	3.56	5.19	5.18
21	71.50	95.98	96.07	40.08	5.60	5.14	7.46	5.45
22	13.05	9.12	5.67	3.25	3.29	3.79	3.10	4.60
23	90.80	121.41	117.82	43.85	6.16	4.75	7.29	7.40
24	16.12	17.63	29.72	13.64	1.64	2.50	2.75	5.02
25	17.71	20.81	35.02	19.51	1.62	2.50	2.42	3.02
26	18.97	20.07	52.35	31.55	1.64	2.83	2.17	1.60
27	21.01	28.73	37.06	17.12	2.51	2.77	2.67	2.28
28	14.50	12.22	51.04	33.05	1.58	1.97	2.05	1.73
29	12.68	11.20	23.30	12.77	1.21	1.95	1.70	3.00
30	23.69	29.84	44.85	40.74	2.51	3.88	4.40	3.64
31	14.88	12.85	45.82	44.47	1.59	2.36	2.76	1.86
32	34.00	47.80	65.30	32.01	3.61	4.01	3.39	3.98
33	26.96	40.07	46.78	20.26	2.52	2.30	2.32	3.21
34	48.89	62.98	64.47	26.51	3.50	3.58	4.49	4.28
35	37.06	56.45	60.93	25.18	2.88	2.69	2.64	3.00
36	30.17	46.42	52.33	21.35	3.23	2.35	2.30	2.73
37	28.20	46.30	61.50	27.42	2.60	3.56	2.47	3.28
38	13.81	11.85	40.67	25.48	1.51	1.73	2.21	2.24
39	19.79	22.19	47.94	28.06	1.42	2.24	2.30	1.69
40	20.16	24.47	42.16	23.55	1.62	1.94	2.84	2.27
41	16.89	15.56	65.40	24.85	2.03	3.13	6.63	3.88
42	59.37	80.92	84.71	36.50	5.20	4.78	4.36	5.31
43	110.43	126.83	126.05	26.18	12.29	0.76	2.61	8.31
44	82.36	110.01	107.26	33.64	4.63	4.52	4.98	8.91
45	69.99	92.73	91.81	23.22	5.71	5.00	6.48	6.88
46	57.77	77.28	78.92	24.24	4.92	4.00	5.72	6.26
47	18.65	18.90	57.39	35.19	1.63	2.76	1.93	1.93
48	39.58	58.12	65.71	43.23	4.44	4.01	4.93	4.75
49	32.87	45.57	55.01	42.69	3.84	3.97	4.84	4.78
50	15.00	12.84	52.25	18.24	1.71	2.34	3.50	3.03
51	13.22	11.62	28.94	16.18	1.27	1.71	2.01	3.53
52	19.39	21.01	48.08	44.15	1.54	2.85	4.05	2.57
53	20.64	26.40	38.61	3.81	3.07	5.32	4.40	2.65
54	20.04	21.74	55.45	17.83	1.98	3.61	3.75	2.94
55	43.24	65.98	74.88	16.92	5.38	4.92	3.86	3.34
56	25.19	31.95	57.44	30.83	2.22	3.52	3.60	3.58
57	11.64	9.69	18.37	10.56	1.57	2.00	1.69	1.87
58	16.72	14.56	65.79	43.52	1.68	2.44	2.32	3.26
59	15.06	13.63	37.10	38.73	2.05	3.33	3.31	2.60
60	39.61	62.45	66.73	27.17	1.99	2.60	2.38	2.31

4.4 REGISTRATION

The purpose of the image registration process is to adjust the geometric location of Landsat data pixels to correlate with ground features represented on 1:24 000-scale U.S. Geological Survey topographic maps. To accomplish this, prominent image features were located on both the Landsat image and on topographic maps. Least-squares solutions were then computed to create image transform coefficients. The coefficients were then used to assign a geographic position for each pixel which matched the area which that pixel would represent on a topographic map.

4.4.1 CONTROL POINTS

Prominent physical features such as lakes, reservoirs, and stream intersections were selected from throughout the entire test site to be used as control points. Displays of the Landsat imagery on the Comtal interactive display console along with printed classification output maps enabled the easy selection of control points. The control points were then transferred to topographic maps so the geographic coordinates for each could be computed. Sixty-six points were initially selected; however, in several cases, either the point was not apparent on the topographic map or no map for that area had been published, and the control point was dropped from consideration. At this stage in the process, 50 control points remained. A further reduction in points was made. Figure 4-4 shows the location of the control points within the San Juan National Forest.

4.4.2 IMAGE TRANSFORMATION

A standard least-squares-fit algorithm was used to calculate image transformation coefficients. The 41 control point locations, previously mentioned, were calculated and analyzed for accuracy. Those control points which made the greatest contribution to the accuracy of the coefficient calculations were selected for use

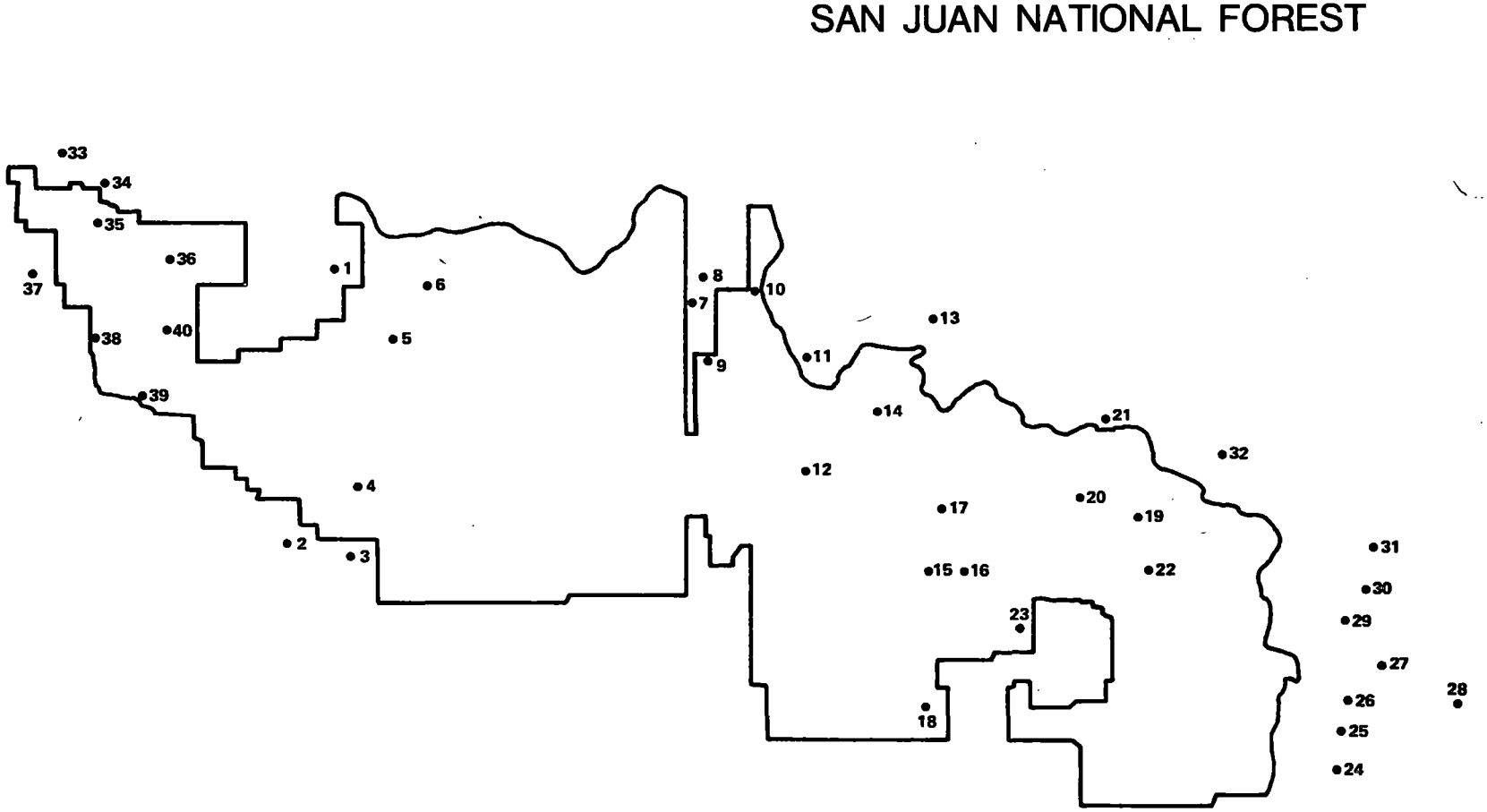


Figure 4-4.– Control point location within the San Juan National Forest.

in the final transformation. This process eliminated nine control points and left a total of 41 final control points distributed over the entire forest. A list of these control points and their location on both the topographic maps and Landsat imagery are in table 4-3.

4.4.3 TOPOGRAPHIC MAP NETWORK FILE

Because the final classification results were to be produced in the form of 19-centimeter (7.5-inch) topographic maps, it was necessary to create a file of geographic coordinate locations which described the topographic map network. This was accomplished by placing a transparent R2MAP grid cell over each topographic map and noting the R2MAP cell row and column along with the geographic coordinates for each of the four corners of the topographic map. In instances where no 19-centimeter (7.5-inch) topographic maps were published, the corner coordinates were estimated.

4.4.4 GRID CELL RESAMPLING

The areal size and geographic location of the Landsat pixels does not necessarily correspond to the size and location of the R2MAP grid cells. Therefore, it was necessary to resample the Landsat classification results in a manner which yielded data cells corresponding to R2MAP cells. To accomplish this, a nearest-neighbor algorithm was used to identify the pixel which is located most centrally for each R2MAP cell. The feature classification label for this central pixel is used to describe the classification for the R2MAP grid cell.

4.5 R2MAP OFFLOADING

The purpose of this step was to produce CCT files of Landsat classification results which can be directly input to the USDA/Forest Service Region 2 computer-based geographic data base information

TABLE 4-3.— CONTROL POINT LOCATION

Control point number	File	File image location		Map coordinates		Description
		X	Y	Latitude	Longitude	
1	E1	147	163	37°47'27"	108°17'25"	Groundhog Reservoir
2	E1	181	687	37°25'26"	108°23'10"	Summit Reservoir
3	E1	354	699	37°23'57"	108°16'32"	Jackson Gulch Reservoir
4	E1	302	533	37°31'10"	108°16'23"	Stream intersect
5	E1	244	219	37°44'32"	108°14'28"	Stream intersect
6	E1	258	166	37°46'41"	108°13'12"	Stream intersect
7	E2	1056	95	37°44'55"	107°40'47"	Molas Lake
8	E2	1049	21	37°48'03"	107°40'05"	Stream intersect
9	E2	1121	180	37°41'00"	107°39'26"	Curve in railroad
10	E2	1207	51	37°45'51"	107°34'17"	Highland Mary Lakes
11	E2	1384	162	37°40'12"	107°28'51"	West Ute Lake
12	E2	1488	328	37°32'38"	107°27'00"	Emerald Lake
13	E3	1667	45	37°43'20"	107°16'03"	Rio Grande Reservoir
14	E3	1616	207	37°36'54"	107°20'20"	Granite Lake
15	E3	1874	483	37°23'49"	107°14'00"	Little Sand River and Piedra River
16	E3	1930	481	37°23'35"	107°11'50"	O'Connel Lake
17	E3	1842	335	37°30'12"	107°13'12"	Williams Creek Reservoir
18	E3	1934	762	37°11'56"	107°15'35"	Capote Lake
19	E3	2293	324	37°27'53"	106°55'25"	Born's Lake
20	E3	2148	328	37°28'36"	107°01'06"	Turkey Lake
21	E3	2158	173	37°35'00"	106°58'35"	Little Goose Lake
22	E3	2355	403	37°24'11"	106°54'05"	Middle Ute Lake
23	E3	2157	614	37°16'38"	107°04'17"	Sullenberger Reservoir
24	E4	2931	714	37°07'39"	106°36'07"	Chama Lake
25	E4	2934	675	37°09'15"	106°35'24"	Trail Lake
26	E4	2926	635	37°10'59"	106°35'06"	Green Lake
27	E4	2930	550	37°14'29"	106°33'48"	Timber Lake
28	E4	2996	625	37°10'58"	106°32'15"	Victoria Lake
29	E4	2889	535	37°15'21"	106°35'11"	Glacier Lake
30	E4	2905	473	37°17'50"	106°33'41"	Tobacco Lake
31	E4	2864	428	37°20'00"	106°34'37"	Platoro Reservoir (west)
32	E4	2431	166	37°33'35"	106°47'46"	Shaw Lake
33	W2	31	324	37°55'56"	108°47'40"	Dolores River
34	W2	143	305	37°56'12"	108°43'06"	Pine Arroyo
35	W2	167	380	37°52'51"	108°43'16"	Pine Arroyo
36	W2	368	487	37°47'12"	108°37'07"	Beef Trail Reservoir
37	W2	49	517	37°47'38"	108°49'34"	Dolores River
38	W2	301	626	37°41'41"	108°41'34"	Five Pine Canyon
39	W2	270	707	37°38'24"	108°43'51"	Dolores River
40	W2	461	655	37°39'32"	108°35'58"	Ferris Reservoir
41	W2	452	605	37°41'43"	108°35'35"	Long's Reservoir

system, R2MAP. The software developed to accomplish this task was a deliverable product for the contract.

4.5.1 MACHINE TO MACHINE CONVERSION

The source machine for this task was the Digital Equipment Company PDP 11/70 minicomputer which has a 16-bit work input/output (I/O) transfer. The receiving machine was a Univac 1100, having a 36-bit word I/O tape controller structure. Incompatibilities existed between the format called for in the project specifications and what may be transmitted in terms of common denominators of integral multiples of 16-bit source machine words and 36-bit receiving machine words.

The Univac standard COBOL header contained 168 field data characters. There were six bits per field data character, resulting in 1008 bits. Dividing this by 16 (bits in a PDP 11/70 word), the integer 63 resulted. This indicated that the COBOL header translation was an integral of word transfers for both machines.

The data blocks posed a more difficult problem. The requirements were to transfer 260 characters of classification image along with 12 characters of special identification (forest number, topographic map number). This gave 272 characters per record. The tapes had to be blocked for 20 logical records per one physical magnetic tape record. Each COBOL logical record had six characters of control information, and each block had an additional six. Therefore, one block of 20 records had to contain 5566 characters. This coverted to 2087.25 PDP 11/70 words, indicating a potential problem of compatibility.

USDA/Forest Service Region 2 personnel provided a sample Univac character tape dump. Examination of this listing showed that there were 5652 characters on the tape and 282 characters

(including COBOL control) per record. The original specifications called for the tape to be in binary coded decimals (BCD), however, during a telephone conversation with Region 2 personnel it was agreed to convert the characters to field data.

4.6 ACCURACY ASSESSMENT

Accuracy Assessment was accomplished by correlating the feature classification results with aerial photography and field data using standard statistical testing methods. The test gave an objective evaluation of the classification results in terms of both accuracy and precision.

The accuracy assessment procedures followed are:

a. Two grids of 100 cells were constructed which covered an area of 2.4 by 4.5 kilometers (1.5 by 2.8 miles). One grid was overlayed on the 1:24 000-scale R2MAP output. The second grid was overlayed to the 1:30 000-scale large-format aerial photography (figure 4-5).

b. Six quad sheets from throughout the forest were selected for evaluation. Figure 4-6 shows the map location within the San Juan National Forest. The maps represented different types of terrain and vegetation. Color-infrared photography of the same area with a scale of 1:30 000 was selected and served as the ground truth.

c. Each quad sheet was then divided into six 100-cell areas and two of these six were randomly selected for evaluation.

d. An alpha-numeric R2MAP printout of each quad sheet was positioned over its respective quad sheet and grid. The R2MAP cover-class cell in the lower left corner of every third grid cell was recorded on the tally sheet.

Figure 4-5.— A large-format aerial photograph of a portion of the San Juan National Forest.

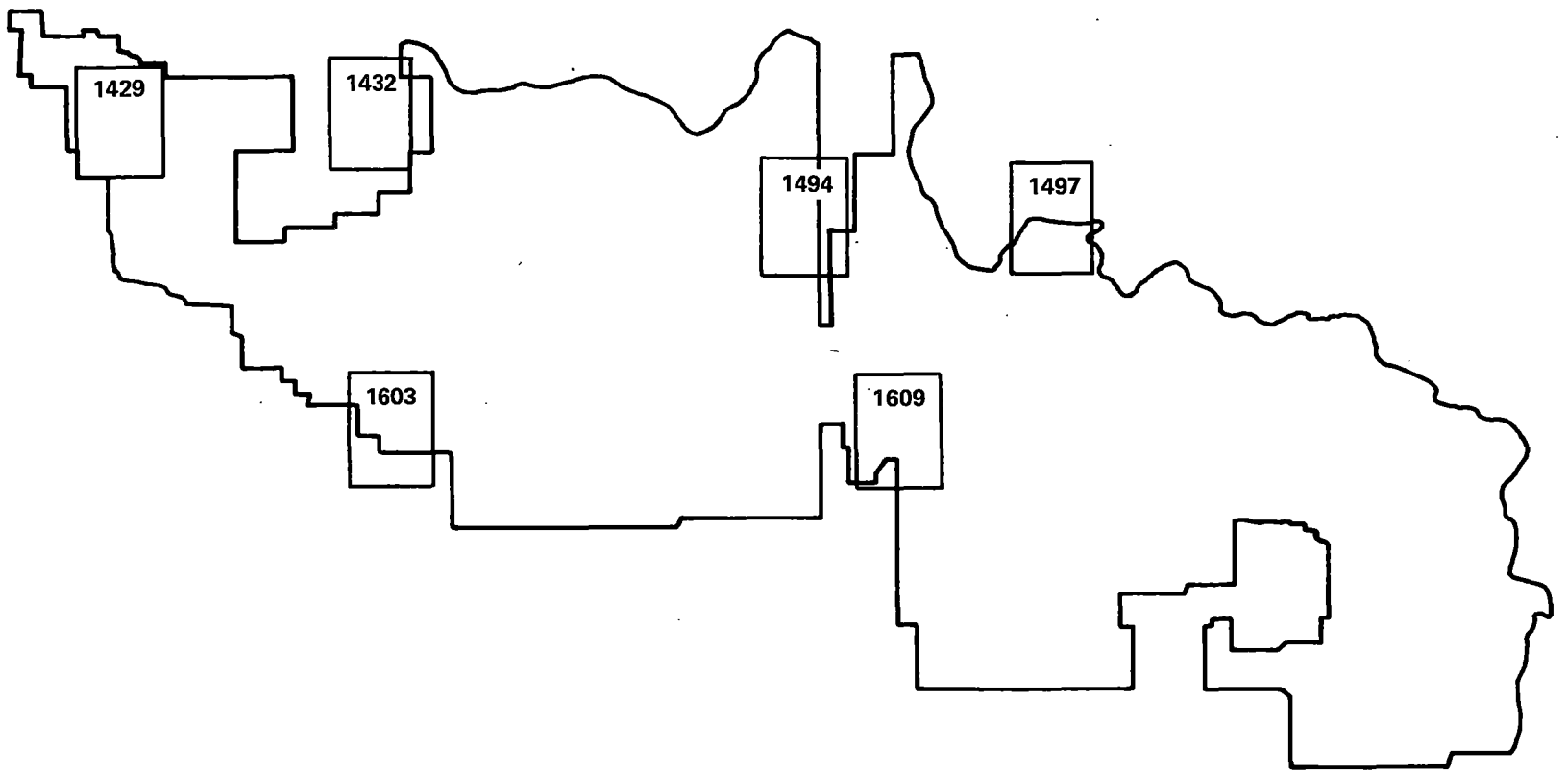


Figure 4-6.— Location of maps within the San Juan National Forest used for accuracy assessment.

e. The grid on the photography was matched, by land feature comparison, with the grid location on the quad sheet. At this point, an interpretation of the land feature in the lower left corner of the grid cell was made and also recorded on the tally sheet.

f. The next step was to compare the photointerpretation with the classification. From this, a percent of correct classification (PCC) was determined for each quad sheet.

g. A confusion table was made from the tally sheets so that an examination of errors could be made.

Figure 4-7 illustrates the accuracy assessment procedures.

4.7 REPORTING

Project reporting consisted of two documentation activities: (1) an interim progress report and (2) a final project report. The interim progress report was an informal description of contract progress for the period from October 11, 1978, through March 1, 1979. The final project report is a formal, detailed description of the project including all activities performed during the period from October 11, 1978, through September 1, 1979.

4.8 REPETITIVE PROCESSING

Because the work was accomplished during the winter season when access to much of the San Juan National Forest was severely curtailed, the procedures listed in section 4.6 (c, d, and e) were performed twice. The interim results, delivered in March 1979, may be revised based on additional field checking which were not performed until July 1979. This field checking was necessary to evaluate both the positional accuracy and classification labeling of the interim product.

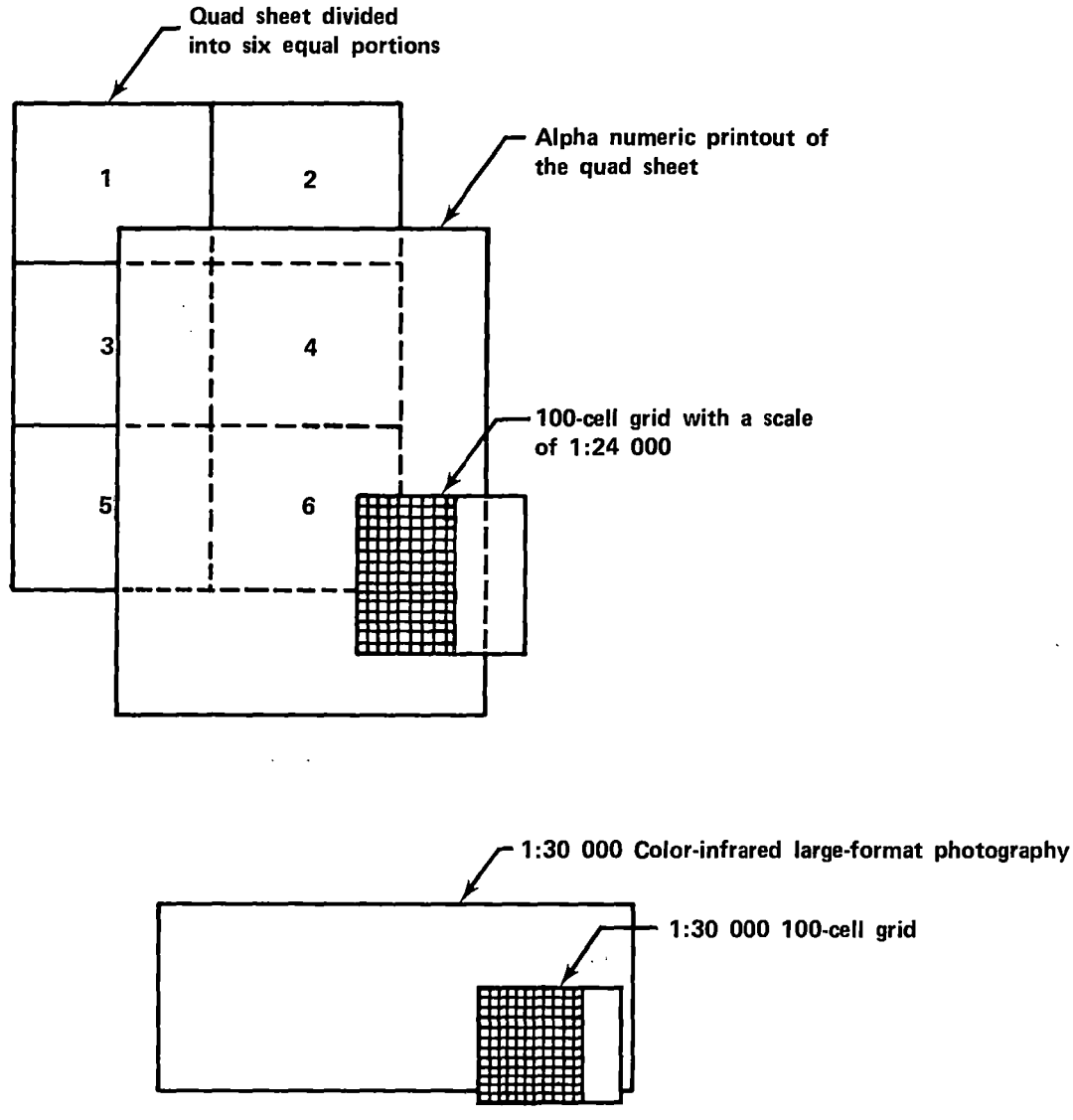


Figure 4-7.— Arrangement of materials used for accuracy assessment procedures.

4.9 PROJECT FACILITIES

The Lockheed Electronics Company, Inc., RSAL provided complete facilities designed to apply the analysis of remotely sensed data to Earth resource management information needs. Of particular interest to this project was the RSAL interactive display and analysis computer system which was used for preprocessing, processing, registration, and R2MAP formatting of the Landsat data and classification results. The system features a PDP 11/70 central processing unit, a Floating Point AP120b array processor, a Comtal Vision 1 interactive display station, and complementary peripheral equipment. Figure 4-8 illustrates the major system components. A description of the RSAL capabilities in more detail may be found in appendix B.

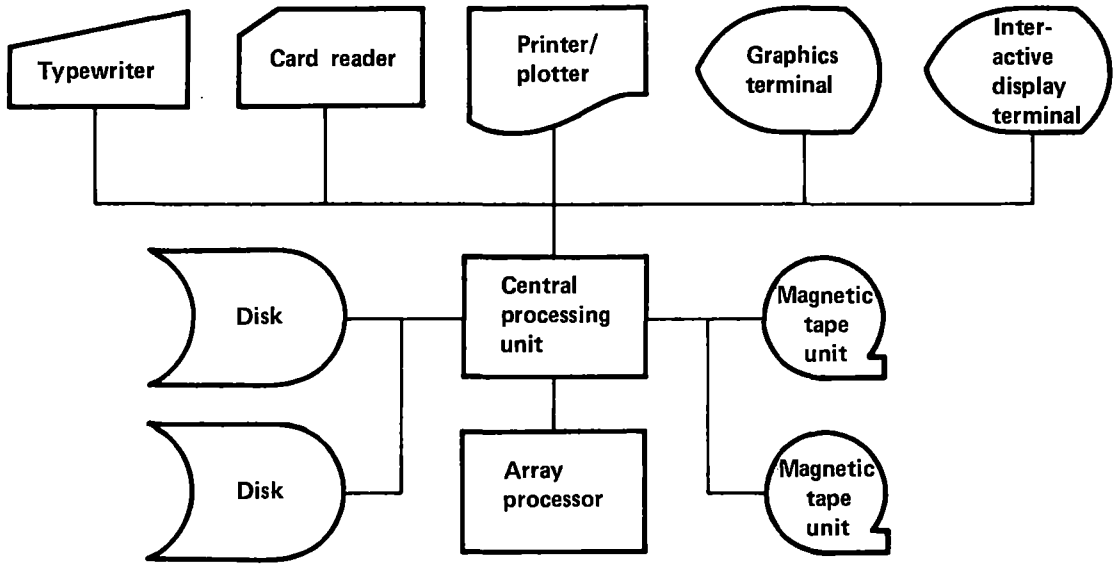


Figure 4-8.— Major computer system components of the RSAL.

5. RESULTS

The results from the feature classification, registration R2MAP offload, and the accuracy assessment are presented in this section.

5.1 FEATURE CLASSIFICATION

Identification of the 60 classes was accomplished by displaying portions of the classified image in a symbolic map format and, when necessary, by displaying classes on the CRT display device overlaying the Landsat image. Data collected during field collection and aerial photography were used as the basis for labeling the classes in respect to the ground features represented. Tables 5-1A and 5-1B list the 60 classes and symbols for the East and West images.

There are three sets of symbols for both the East and West Images. Each set of symbols represents a different classification tape. The first set represents the R2MAP format tape. On this tape, each cluster is kept separate from the other except for five snow clusters and two bare rock clusters. The reason for these seven combinations is that the printer at the Fort Collins Computer Center did not have enough symbols to portray all 60 clusters. The first symbol on this set represents a land feature. The second symbol, a number 1-5, represents crown closure as follows: 1 represents a crown closure of 0 to 30 percent; 2 represents 31 to 50 percent; 3 represents 51 to 70 percent; 4 represents 71 to 100 percent; and 5 represents crown closure not applicable to the land feature.

The second set of symbols is still in the R2MAP format; however, a combination of similar classes identified by one symbol was made. For instance, all 14 classes of snow are represented by the symbol "X5". As in the first set of symbols, the second symbol (a number) represents crown closure. This tape should

TABLE 5-1A.— SYMBOL AND LAND FEATURE IDENTIFICATION

East Image				
Cluster number	R2MAP symbol	Combined R2MAP symbol	1-cell to 1-pixel symbol	Land feature[a]
1	02	02	1	Oakbrush 31-50%
2	X5	X5	.	Snow
3	C4	C4	C	Douglas fir-white fir, Ponderosa pine, spruce-fir 71 to 100% Ponderosa pine 51 to 70%
4	P4	C4	C	Same as cluster number 3
5	M5	M5	M	Wet mesic grassland including some alpine
6	G5	G5	3	Grassland and alpine
7	$2	$2	(	Aspen 31 to 70% (some oak is included)
8	04	04	4	Oak
9	I5	I5	I	Rocky grassland
10	A3	A3	V	Aspen 51 to 70%.
11	.5	X5	.	Snow
12	%5	%5	"	Bare soil with sparse grass
13	.5	X5	.	Snow
14	,5	X5	,	Snow
15	,5	X5	,	Snow and bare soil
16	;5	X5	;	Rock and snow
17	E2	E2	E	Aspen oak conifer 31 to 50%
18	J1	J1	5	Pinyon-juniper 0 to 30%, lower elevations sparse conifer and grass in high country
19	65	I5	6	Rocky grassland
20	Y3	A3	Y	Aspen 51 to 70%, may also include cultivated or wet mesic grassland
21	,5	X5	,	Snow
22	W5	W5	W	Water
23	¦5	X5	¦	Snow
24	P1	P1	P	Ponderosa pine, Douglas fir-white fir 0 to 30%
25	P3	P3	7	Ponderosa pine;pinyon-juniper;highland grass
26	83	03	8	Oakbrush 51 to 70%, including some grassland, alpine, and aspen
27	"5	R5	"	Bare rock and snow
28	03	03	0	Oakbrush 51 to 70% (may include aspen)
29	S4	S4	S	Spruce-fir 71 to 100% (shadows may have an effect)
30	]5	]5	]	No data

[a]When more than one land feature is listed by one cluster, they go from the most dominant to the least dominant.

TABLE 5-1A.– Concluded.

East Image				
Cluster number	R2MAP symbol	Combined R2MAP symbol	1-cell to 1-pixel symbol	Land feature
31	!5	=5	=	No data
*32	⌀5	R5	!	Rock or soil
33	R5	R5	R	Bare rock
34	-5	X5	-	Snow
35	,5	X5	,	Snow and rock
36	R5	R5	R	Bare rock
37	"5	X5	"	Rock and snow
38	H4	H4	H	Conifer-aspen 71 to 100% (shadow may have an effect)
39	⌀2	⌀2	G	Pinyon-juniper and some ponderosa pine 30 to 50% (contains some pixels above timberline)
40	&1	&1	&	Pinyon-juniper and ponderosa pine 0 to 30% (much grass shows through)
41	:5	:5	:	No data
42	:5	:5	-	Alpine
43	+5	X5	+	Snow
44	*5	X5	*	Snow
45	@5	@5	@	Shadow in snow
46	,5	X5	,	Snow
47	94	94	9	Wet grassland, oak, or aspen 0 to 30%
48	"5	%5	"	Rock and alpine grass
49	)5	G5	)	Low grassland
50	Z5	Z5	Z	No data
51	D3	D3	D	Douglas fir-white fir, white fir, spruce-fir 51 to 70% (shadow may have an effect)
52	<5	<5	<	Crops
53	R5	R5	R	Bare rock
54	$5	$5	$	No data
55	⌀5	⌀5	⌀	No data
56	/5	/5	/	Grassland including apline (may have some sparse conifer
57	#5	#5	#	Spruce-fir, water, shadow 71 to 100%
58	A4	A4	A	Aspen 71 to 100%
59	X5	X5	X	No data
60	%5	%5	%	Exposed soil and alpine

*R2MAP symbol (⌀) represents blank area on printout.

TABLE 5-1B.— SYMBOL AND LAND FEATURE IDENTIFICATION

West Image				
Cluster number	R2MAP symbol	Combined R2MAP symbol	1-cell to 1-pixel symbol	Land feature
1	U5	U5	U	No data
2	V5	V5	V	No data
3	F2	F2	F	Ponderosa pine-oakbrush 31 to 50% Oakbrush-aspen 31 to 50%
4	01	01	4	Oakbrush 0 to 30%
5	,5	G5	,	Grassland
6	G5	G5	G	Grassland
7	04	04	Ø	Oakbrush 71 to 100%
8	%5	%5	%	No data
9	<5	<5	<	Crops
10	02	02	*	Oakbrush
11	=5	=5	=	No data
12	35	G5	3	Grassland
13	/5	/5	1	Bare soil
14	/5	/5	/	Bare soil
15	55	G5	5	Grassland
16	75	G5	7	Grassland
17	24	04	2	Oakbrush 71 to 100%
18	85	G5	8	Grassland
19	&5	G5	&	Grassland
20	<5	<5	<	Crops
21	.5	/5	.	Bare soil
22	W5	W5	W	Water and shadow
23	]5	]5	(	No data
24	J4	J4	J	Pinyon-juniper 71 to 100%
25	(5	G5	9	Grassland
26	02	02	1	Oakbrush 31 to 50%
27	)5	G5	)	Grassland
28	A4	A4	A	Aspen 71 to 100%
29	B4	B4	$	Mixed brush 71 to 100%
30	M5	M5	M	Wet mesic grassland

TABLE 5-1B.– Concluded.

West Image				
Cluster number	R2MAP symbol	Combined R2MAP symbol	1-cell to 1-pixel symbol	Land feature
31	95	95	]	No data
32	/5	/5	/	Bare soil
33	I5	G5	I	Grassland
34	@5	@5	@	No data
35	R5	R5	R	Bare rock
36	!5	/5	!	Bare soil
37	.5	/5	.	Bare soil
38	03	03	0	Oakbrush 51 to 70%
39	B3	B3	B	Mixed brush 51 to 70%
40	T3	T3	T	Oak/conifer 51 to 70%
41	<5	<5	<	Crops
42	.5	/5	.	Bare soil
43	Q5	A5	Q	No data
44	N5	N5	N	No data
45	Y5	Y5	Y	No data
46	"5	G5	"	Grassland
47	<5	<2	<	Crops and possibly some oakbrush
48	<5	<5	<	Crops
49	Z5	Z5	Z	No data
50	01	01	1	Oakbrush
51	F3	F3	F	Conifer-oak 51 to 70%
52	<5	<5	<	Crops
53	:5	/5	:	Bare soil
54	;5	R5	;	Rock
55	Ø5	Ø5	Ø	No data
56	+5	G5	+	Grassland
57	#5	#5	#	Shadow
58	<5	<5	<	Crops
59	X5	X5	X	No data
60	65	G5	6	Rocky grassland

help to eliminate confusion that might be encountered when examining a printout of the 60 clusters.

The third set of symbols is a representation of the "one cell equals one pixel" data set. (This tape was made at the request of the USDA/Forest Service and was written as a modification to the initial contract.) This tape does not contain a symbol indicating crown closure. However, the individual cluster may-be identified as a forest type with its crown closure included in the identification. An example of this classification is cluster 29 in table 5-1A. The cluster is represented by the symbol S which was identified as spruce-fir, 71 to 100 percent.

Under the column headed Land feature there are some blanks. These blanks indicate classes where no pixels could be seen for identification or no pixels existed at all. In either case, the pixel ontent was insignificant and it would not have been practical to search out the land feature they represented. At this point the class labeling scheme was transferred to the R2MAP offloading subsystem.

5.2 R2MAP OFFLOAD PROGRAM

The absolute program, SJNF, was written to offload classification results in R2MAP format. This program was stored in the PDP 11/70 library. It was intended that this task be run as a batch job. Aside from the standard job card, the only job control card required was a mount card. This called for a foreign tape to be mounted in either tape unit desired.

The data cards and their interpretation follow. They were supplied in the order shown.

Card	Use	Value
1	Mag tape unit designator (MTU)	0 or 1
2	Debug Flag (IDBUG) – (prints I/O and associated counters)	0 for no debug ≠ for debug
3	Number of lines (NLINS) – to be processed	Should be 210 but may be changed; fixed to one value throughout one program execution
4	Translate Flag (IXLATE) – specifies identification of any class for which there is not a defined output symbol. Note: class zero and classes greater than 62 are not allowed. For such values two question mark symbols (??) are inserted.	0 for no translate ≠ for translate
5	File Name (FNAM) – maximum of 12 characters; 99 such files may be processed. Note: if crossing of user identification code (UICs) is required, this may have to be expanded.	any legal programmed data processing file name
6	Quad Number (QUAD) – a four-character number that associates a file with a particular quad number. If quad is 1, it must be entered as 0001.	4 characters

Up to 99 file names and quads could be specified. All other parameters were fixed for this session. Cards 5 and 6 were repeated pairwise as required. The last card was a $EOJ followed by standard end-deck procedures.

The line printer (FORTRAN device) received all messages, queries, and final statistics. A summary of the files processed and their respective quads were printed at the end of the run and served as a tape transmittal identification.

5.2.1 SUMMARY OF PROGRAM ROUTINES

The following is a summary of the routines used in program SJNF and what they accomplished.

Program SNJF	Main program
BLOCK DATA SJNF	Initialize debug variables and establish character mapping
COBHDR	Sets of COBOL header for O/P tape
COBCTL	Accepts quad number (QUAD), inserts it into the standard COBOL control word group, and stores where specified by the block and J arguments. Block is a byte array, and J is the beginning byte for storage.
XLATE	Subroutine to convert the VIDEO image cluster numbers to the proper map characters. Accepts 5 arguments: A, M, J. B, N. A is the byte input array; M is the starting byte of cluster digits; J is the number of bytes to process; B is a byte output array; N is the beginning byte in the output array. If a class is out of domain (either zero or greater than 62), two question marks are output as the map symbols.
ROWNO	This subroutine accepts an octal integer and converts it to a 4-character value. The last three (positions 2 through 4) are stored in the array specified by the argument B at the 5*th* character. Note: this is part of the forestry control character.
PACK	This is an assembly subroutine which accepts a source array of 6-bit characters, right justified in each 8-bit byte, and packs a specified number of them into a receiving array. This forms the tape output images.

ASC2FD	This subroutine converts ASCII characters to field data via a look-up method (not very fast or efficient but easy to code). The arguments are accepted: A, I, J, B, and K. A is a byte array of ASCII characters; I is the starting position in the input array; J is the number of characters to process; B is the output array (byte); and K is the first receiving position. Any character that cannot be translated to one of the 64 field data characters receives a question mark character.

5.2.2 PROGRAM COMPILATION

A program compilation for the R2MAP Offload Program SJNF is included in appendix C.

5.2.3 PROGRAM STATUS

Test tape files prepared using the SJNF program were transmitted to Region 2 during January and February 1979. The tapes were read into the Fort Collins Computer Center Univac system. In two tests, the header was read without problem, as anticipated. As also anticipated, it was not possible to read the file beyond the first data record. Modifications were made to the program which made the interim product files compatible to the Univac I/O system, as verified in a third test.

There were, however, some problems in reading the header to each record in the final classification tapes mailed to Fort Collins. The problem occurred when programmers had to make modifications in the symbol identification of the 60 classes. The tapes for the interim phase simply doubled the pixel to complete an R2MAP cell. For the final tapes, the first symbol indicated the class type, and the second symbol indicated the crown closure, thus creating a need to modify the program.

The problem was detected and corrected within a week. New tapes were written and mailed to the Fort Collins Computer Center on July 6, 1979. These tapes were read with no problems, and alpha-numeric printouts were produced. The printouts were examined in the field by USDA/Forest Service personnel and Lockheed Electronics Company, Inc., scientists. For a detailed analysis of the final product, see section 6, Analysis of Results. The final tapes were mailed on August 28, 1979. They contained some symbol changes found necessary during evaluation and a more accurate registration.

5.3 REGISTRATION ACCURACY

The error in both the X- and Y-axis for each control point used for registration of data and the associated root-mean-square (RMS) error are shown in table 5-2. The RMS is under 1.0 for the X- and Y-axis on both the East and West Images; this fulfills the USDA/Forest Service requirements.

Five quadrangle maps representing the National Forest from the eastern side through the western portion were selected and checked. On each of these maps, three to five points were checked for their positional accuracy by overlaying a map and examining land feature detail. The land features were within a pixel in positional accuracy.

5.4 ACCURACY ASSESSMENT

In order to accomplish the accuracy assessment phase, the symbols from the combined cluster map (column 2 of table 5-1A and 5-1B) were used.

The percent of correct classification of the 60-cluster map when compared with aerial photography are reflected in table 5-3 for land cover and crown closure classification accuracies.

TABLE 5-2.– FINAL CONTROL POINTS AND ASSOCIATED ROOT MEAN SQUARE (RMS) ERROR

[The calculated East Image error for X is 0.8529 and for Y is 0.4838.
The calculated West Image error for X is 0.4707 and for Y is 0.5203.]

Control point	X-axis error (pixels)	Y-axis error (pixels)	Control point	X-axis error (pixels)	Y-axis error (pixels)
1	0.15193	0.43786	22	0.05265	-0.58228
2	-0.13388	-0.20847	23	1.16390	0.29515
3	0.03184	-0.55037	24	1.47837	0.75540
4	-0.68617	-0.56636	25	-1.33487	0.81468
5	-0.83248	0.91538	26	-0.27469	0.61191
6	-0.66434	-0.16260	27	0.13246	-0.02187
7	0.39037	0.32302	28	-1.14117	0.15897
8	-0.73249	0.13343	29	-0.08567	-0.31818
9	-0.59207	0.31501	30	-0.96255	0.51258
10	-0.82376	0.28452	31	-1.31734	0.23106
11	-0.48013	-0.49798	32	-1.05979	-0.77574
12	0.98174	0.21823	33	-0.75434	0.73547
13	0.43377	-0.44047	34	0.48157	-0.89852
14	0.01694	-0.03003	35	-0.38164	-0.07112
15	1.90231	0.68123	36	0.44067	0.04067
16	0.40756	0.24540	37	0.69593	0.40361
17	1.31245	-0.18962	38	-0.08863	-0.59459
18	0.16279	-0.83283	39	-0.15271	-0.43123
19	0.32953	-0.41074	40	-0.51324	0.55754
20	0.45582	-0.57990	41	0.27238	0.26047
21	1.70097	-0.16363			

TABLE 5-3.— THE 95% CONFIDENCE INTERVALS OF THE PERCENT CORRECT CLASSIFICATION FOR LAND COVER CLASSES AND CROWN CLOSURE USING A 60-CLUSTER MAP

Land cover classes, percent	Crown closure, percent
*71.3 ± 4.55	58.7 ± 4.96

*The values obtained for this PCC is a result of an interpretation of the confusion tables 6-1 and 6-3. Section 6 of this report gives a detailed explanation of the interpretations made from these tables.

Table 5-4 shows the results of a Level II classification made by combining all conifers into one class, the hardwoods into one class, and the mixed conifer and hardwood into another. All other land features remained separate. When these classes are used, the 95 percent confidence interval of the PCC changes to 78.9 ± 4.1 percent accuracy for the combined East and West Images. However, it is no longer possible to determine individual crown closure for each class because they have all been grouped into one class.

TABLE 5-4.— THE 95% CONFIDENCE INTERVALS OF THE PERCENT CORRECT CLASSIFICATION FOR LAND COVER CLASSES USING LEVEL II LAND FEATURE CLASSES

Land cover classes, percent
78.9 ± 4.1

The accuracy of classification for the 12 blocks of the 100 cells on six quad sheets is presented in table 5-5. The data used to compile these summary tables was recorded on tally sheets. Figure 5-1 is an example of a tally sheet.

TABLE 5-5.— THE PCC FOR EACH QUAD SHEET SECTION

East Image			
Quad sheet name	Quad number	Quad sheet section number	PCC
Vallecito Reservoir	1609	3	87.0
Vallecito Reservoir	1609	5	76.0
Groundhog Reservoir	1432	4	76.0
Groundhog Reservoir	1432	3	67.0
Millwood	1603	2	65.0
Millwood	1603	5	62.0
Snowdon Peak	1494	3	82.0
Snowdon Peak	1494	6	64.0
Weminuche Pass	1497	3	73.0
Weminuche Pass	1497	5	74.0
West Image			
The Glade	1428	2	74.0
The Glade	1428	4	66.0

SAN JUAN NATIONAL FOREST TALLY SHEET

Point	Photographic feature	ADP classification feature	Correct classification	Point	Photographic feature	ADP classification feature	Correct classification
1				73			
4				76			
7				79			
10				82			
13				85			
16				88			
19				91			
22				94			
25				97			
28				100			
31							
34							
37							
40							
43							
46							
49							
52							
55							
58							
61							
64							
67							
70							

Figure 5-1.— Example of a tally sheet.

6. ANALYSIS OF RESULTS OF CLUSTER IDENTIFICATION

At a conference with San Juan National Forest personnel in Houston, Texas, the clusters representing the land features within the forest were identified. A portion of the National Forest around Vallecito Reservoir and another around the Glade were used to represent the vegetation on the East and West Images, respectively. The Comtal (an interactive device in the RSAL for video display) was used to examine all 60 clusters for both scenes. Each cluster was identified as to the land feature and, if applicable, the crown closure that it portrayed. The next step was to assign the cluster a symbol. One advantage of this system to identify clusters is flexibility. If a consistent error is found in classification, the process to correct it is relatively simple. All that must be done is to change the cluster identification symbol (section 5, table 5-1A and 5-1B). Or, if a new symbol is desired, a simple change on one of the computer cards can be made and a new tape generated. For example, if a detailed field examination was made and cluster 18 (symbol 85) of the West Image was classified forest more often than grassland, then adjustment of the land feature column to forest is all that is necessary.

Most of the area observed for cluster identification was mountainous terrain with elevations ranging from 2438.4 meters to over 3962.4 meters (8000 to over 13 000 feet), and the area ranked high in PCC. However, one of the quad sheets evaluated (1603, the Millwood quad sheet) was in the south-central portion of the forest and had a very different terrain and vegetation. The results of the classification were poor because it was assumed

that the clusters identified in one place would be the same as in another. To correct this misconception, the scientist could divide the forest into portions of similar terrain and vegetation and do a cluster identification for each portion of the forest.

In some cases it may appear that a cluster is totally out of place, such as oakbrush shown where alpine or aspen should be represented. Under certain conditions, these vegetation types have spectral-value differences which are too subtle for detection in a generalized classification operation. Therefore, at this point the user must add the necessary ancillary data to separate the types.

Assessment of the confusion in classification between photointerpretation and ADP during the San Juan National Forest project is presented in this section. Land features and crown closure were evaluated as two separate layers of data. Confusion tables 6-1 and 6-3 show land feature classification results for the East and West Images, whereas the crown closure results may be seen in tables 6-2 and 6-4. The horizontal listing in the tables is of the classes from the computer printout; the vertical column is a list of classes found by the photointerpreter.

Tables 6-1 through 6-4 deliver the results of an objective unbiased evaluation of the computer processed data. At times, however, it is equally important to include a subjective interpretation of such a table to achieve representative results. Some of the class definitions include more than one land feature; i.e., symbol "P" represents two forest types, (a) ponderosa pine-Douglas fir and (b) ponderosa pine-pinyon pine-juniper. When a situation such as this occurs, the image analyst must decide the results using his or her interpretative skills. Another example of the need for subjective interpretation is the vague land feature definitions.

TABLE 6-1.— CONFUSION TABLE FOR LAND FEATURES OF THE EAST IMAGE ACCURACY ASSESSMENT

		Automatic data processing class																		
		C	S	D	P	J	G	I	R	W	H	E	O	A	M	X	T	F	Total	Omission Error	Percent Omission
Douglas fir-white fir, Ponderosa pine, spruce-fir)71 to 100% Ponderosa pine 51 to 70%	C	27	4	13	5		1				2	1	2						55	28	51
Spruce/fir	S	8	16	7	4		4	1	1										41	25	61
Douglas fir-white fir, white fir, spruce-fir	D	2		0															2	2	0
Ponderosa pine-Douglas fir Ponderosa pine-pinyon-juniper	P	1			21	6	3												31	10	32
Pinyon-juniper, some Ponderosa pine	J					10	1												11	1	9
Grassland and Alpine	G	3		1	9	12	40		1				5	1	1	1			74	37	50
Rocky grassland	I	1					6	3	3										13	10	77
Bare rock	R		1				1		12										14	2	14
Water	W									7									7	0	0
Conifer-aspen	H										15	4							19	4	21
Aspen-conifer	E	1			1							3	1						6	3	50
Oakbrush	O						3					2	18						23	5	22
Aspen	A				1								4	8					13	5	38
Wet mesic grassland including some alpine	M														0				NA	NA	NA
Snow	X															1			1	0	0
Oak-conifer	T						1				1	1					0		3	3	100
Conifer-oak	F				1							3						0	4	4	100
Total		43	21	21	42	28	60	4	17	7	18	14	30	9	1	2	NA	NA	317		
Commission error		16	5	21	21	18	20	1	5	0	3	11	12	1	1	1	NA	NA			
Percent commission		37	24	100	50	64	33	25	29	0	17	79	40	11	100	50	NA	NA			

TABLE 6-2.– CONFUSION TABLE FOR CROWN CLOSURE OF THE EAST IMAGE ACCURACY ASSESSMENT

Automatic Data Processing Class

Aerial Photo Class	Crown Closure		Conifer				Mixed				Hardwood				No Crown Closure	Total	Omission Error	Percent Omission
	Crown Closure		4	3	2	1	4	3	2	1	4	3	2	1	5			
Conifer	71-100%	4	41	17	0	3	2		1			2			1	67	26	39
	51- 70%	3	13	4	1	2									4	24	20	83
	31- 50%	2	13	1	2	17									5	38	36	95
	0- 30%	1	0	1	0	9									1	11	2	18
Mixed	71-100%	4					15		4						0	19	4	21
	51- 70%	3	1				1		6						1	9	9	0
	31- 50%	2	2						3						0	5	2	40
	0- 30%	1													0	0	0	NA
Hardwood	71-100%	4													0	0	0	NA
	51- 70%	3				1						23	1		0	25	2	8
	31- 50%	2										3	4		2	9	5	56
	0- 30%	1													1	1	1	0
	Crown Closure	5	7	1	3	16						5	1		76	109	33	30
	Total		77	24	6	48	18	0	14	0	0	83	6	0	91	317		
	Commision Error		36	20	4	39	3	0	11	0	0	10	2	0	15			
	Percent Correct		47	83	67	81	17	NA	79	NA	NA	30	33	NA	16			

TABLE 6.3– CONFUSION TABLE FOR LAND FEATURES OF THE WEST IMAGE ACCURACY ASSESSMENT

Aerial photo class		Automatic data processing class												
		B	F	J	G	O	T	<	8	2	5	Total Samples	Omission Error	Percent Commission
Mixed brush	B	1										1	0	0
Ponderosa pine-oakbrush	F	2	8		1		1	3		1	1	17	9	53
Pinyon-juniper	J			1	1	1		1	2			6	5	83
Grassland	G				17		2	1				20	3	15
Oakbrush	O	2				7						9	2	22
Oak-conifer	T						10					10	0	0
Crops	<							0				0	NA	NA
Grassland	8								0			0	NA	NA
Oakbrush	2									0		0	NA	NA
Grassland	5										0	0	NA	NA
Total samples		5	8	1	19	8	13	5	2	1	1	63		
Commission Error		4	0	0	2	1	3	5	2	1	1			
Percent Commission		80	0	0	5	15	23	100	100	100	100			

TABLE 6-4.– CONFUSION TABLE FOR CROWN CLOSURE OF THE WEST IMAGE ACCURACY ASSESSMENT

Automatic Data Processing Class

Aerial photo class			Conifer				Mixed				Hardwood				No Crown Closure	Total	Omission Error	Percent Omission
	Crown Closure		4	3	2	1	4	3	2	1	4	3	2	1	5			
Conifer	71-100%	4	1													1	0	0
	51- 70%	3												1	1	2	2	100
	31- 50%	2													3	3	3	100
	0- 30%	1														0	0	NA
Mixed	71-100%	4														0	0	NA
	51- 70%	3						13			1				3	17	4	24
	31- 50%	2							2						2	9	4	44
	0- 30%									1						1	0	0
Hardwood	71-100%	4									2					2	0	0
	51- 70%	3										2				2	0	0
	31- 50%	2									1	1	2			4	2	50
	0- 30%	1												2		2	0	0
	No Crown Closure	5						2							18	20	2	10
	Total		1	0	0	0	0	15	5	1	6	3	2	3	27	63		
	Commission Error		0	0	0	0	0	2	0	0	4	1	0	1	9			
	Percent Commission		0	NA	NA	NA	NA	13	0	0	67	33	0	33				

This is seen with the symbol "I", rocky grassland. When does a grassland become rocky or, as with symbol "M", when is a grassland wet? Once again it is a classification that must be interpreted by the image analyst. Natural resources, such as the forest studied for this project, cannot be confined to uniform classifications all the time. Therefore, for full value from Landsat, the interpretative skills of an image analyst is necessary.

The purpose of this section is to offer an explanation of the confusion tables. As each class is discussed, the reader should refer to both tables 6-1 and 6-3.

The overall forest PCC results shown in section 5 included the consideration if a classification was similar such as between combined conifer (symbol C) and spruce (symbol S) or a complete-miss as between aspen (symbol A) and pine (symbol P).

The PCC's for this project represent the highest possible agreement of Landsat to photos when the above-mentioned problems are considered. To understand how the PCC's were obtained, follow the discussion on the methods used.

The combined conifers (C) class was originated at the time USDA/Forest Service personnel visited Houston. This class represents a mixture of conifers such as spruce-fir, Douglas fir-white fir, and sometimes ponderosa pine. The combined conifer cluster (C) occurred 43 times and, of those, was called (C) 27 times; was associated with the other conifer types 11 times; and was associated with unrelated classes such as with grassland (G) 3 times and one time each with aspen-conifer (E) and rocky grassland (I). Symbol C on the printout was correctly interpreted as some type of conifer, excluding juniper-pinyon, 84 percent of the time. It may be considered an accurate class.

If all the conifers were grouped into one Level II class as in section 5, table 5-4, the PCC would be 78.9 $\pm$ 4.1 percent.

The spruce-fir forest was most often confused with the Douglas fir-white fir forest and then the ponderosa pine forest. At times, the photointerpreter found difficulty in distinguishing between the spruce-fir and Douglas fir-white fir during the evaluation. For this reason the more inclusive class (symbol C) was used during photointerpretation. If an S or D occurred on the printout and if a C had been the photointerpretation of a particular area, it was considered a "hit" and counted as a correct classification. It was much easier, however, to photo-interpret ponderosa pine because of the elevation stratification. Therefore, if an S occurred on the printout and a P was the photointerpretation, it was a "miss" and would not be considered a correct classification.

In table 6-1, observe that the spruce-fir (symbol S) was called combined conifers (C) four times and S 16 times. There was confusion with one unrelated class, bare rock; therefore, it is assumed that spruce-fir (S) is a very reliable classification.

The Douglas fir-white fir forest (D) was most often classified as combined conifers (C). It was called grassland (G) one time. The probable reason for D being called grassland follows: as the computer averaged the values of the nine pixels in question, the grassland signature was slightly more dominant than conifer.

Ponderosa pine forest (symbol P) occurred 42 times on the print-outs. They were correctly matched with ponderosa pine 21 times and combined conifers 5 times. In addition, they were incor-correctly matched with spruce-fir (S) 4 times. These errors are understandable, but the pine forest also went into grassland (G) 9 times, aspen once, and a mixture of conifer-hardwood twice.

The pinyon-juniper forest was classified correctly 16 times, 11 times as a pure pinyon-juniper forest and 6 times as a ponderosa pine-pinyon-juniper forest. The only confusion was with grassland (G) where it occurred 12 times. When examining the pinyon-juniper cluster on the Comtal, it dominated the lower elevations, and ground truth indicated it to be pinyon-juniper even though the same cluster occurred on grasslands in the higher elevations. It could, therefore, possibly be considered correct in both cases. For the purposes of this report, however, it was called a "miss" if it did not land on a pinyon-juniper forest. Because this forest type often grows in bunches with large grass areas interspersing the forest, it may be assumed that some of the pinyon-juniper clusters are lost in the grassland and brush clusters.

Grassland (G) was by far the most common class to be found because forests with less than 25-percent crown closure would quite often be classified as grass. The sensor averages the reflectance values within the Landsat pixel, and in this class, the pixel is dominated by grass. These sites plus the true grassland sites produced a large class. There were seven clusters of grassland on the East Image and 12 on the West Image. The photointerpreter could not break out all these clusters of grassland with repeatable accuracy; therefore, all grasslands were grouped into one class for the evaluation.

Looking at tables 6-1 and 6-3, it may be seen that the grassland class (symbol G) was called G 54 times or 73 percent of the time. A wide distribution of error sources was evident, including conifers, hardwoods, brush, and mixture. If an error occurred more than three times, the printout was examined to see if re-labeling was necessary. The cluster (symbol 8), a subdivision of grassland, was interpreted from the photography as oakbrush seven

times. When the final tape was created, it was relabeled and grouped into the oakbrush class. It was also found that grassland clusters (symbols 7 and 5) would better represent a ponderosa pine and pinyon-juniper forest, respectively. The final tapes contain all these changes. Rocky grassland (I) was an associated error and happened six times. Again, a relabeling may be necessary. The thirteen errors of confusing grassland with conifers, on Table 6-1 and 6-3, may be caused by the greater reflectance value of grass through an open canopy. Rocky grassland was classified as rocky grassland three times and as spruce-fir (S) once.

Six clusters were assigned to the alpine class by examining the data on the Comtal. Some of the alpine clusters also contained data representing grass valleys in the lower elevations. The alpine classes were separable as a class only with support from elevation data. A computer prinout and knowledge of the location on the quad sheet will help the user distinguish alpine from valley grasses. Therefore, both types of grassland had to be combined into the class (G).

A similar problem occurred with willowbrush. These clusters were classified as aspen and grass. When in the field, it was noted that aspen did not generally grow above 4200 meters (10 500 feet), whereas willowbrush grew well at this elevation and continued to do so until it reached bare rock. Therefore, the clusters registered at this elevation were probably willowbrush.

The class bare rock (R) was found throughout the site with the highest elevations containing most of the class. Bare rock (R) was correctly classified as bare rock 12 times, grassland (G) once, rocky grassland (I) 3 times, and spruce-fir (S) one time.

Water (W) was classified very accurately. In this study water was classified as water seven times. Although no misclassifications were found here, errors could occur due to a difference in the water level of the reservoirs between the dates of Landsat imagery and the aerial photographs. The computer printout indicated that cluster 22 was pure water. Cluster 57 of the East Image was water, but included some spruce-fir forest. Most of the larger reservoirs such as Vallecito, Lemon, and Groundhog Reservoirs had a ring of cluster 57 (one-pixel wide) all the way around the perimeter of the water body. This may have been caused by the shallow water depth. If so, many of the smaller mountain lakes on the East Image may be represented by cluster 57 with the symbol (#). The West Image had some confusion between water and shadow along the Dolores River canyon.

The conifer-aspen class (symbol H) was a moderately accurate class. It was classified as H 15 times and called combined conifers (C) two times and conifer-oak (T) one time. None of the errors are totally off, but all were called a "miss" during evaluation.

The results of the aspen-conifer class (E) were not as good as the inverse class of conifer-aspen. The aspen-conifer was correct only 3 times. Errors included combined conifers (C), conifer-aspen (H), oakbrush (O), oak-conifer (T), and conifer-oak (F). The errors, although counted as incorrect ones, are related to the class. It is a common problem to have trouble separating mixed vegetation types such as these with the Landsat sensor. Homogeneous forests usually have more accurate classification results and are much easier to classify.

Oakbrush (symbol O) was found over much of the San Juan National Forest and correctly classified 63 percent of the time; i.e., 25 out of 39 times. The most common source of error was with

grassland, and that occurred five times. Other errors were four with aspen, two with combined conifers, one with aspen-conifer, two with pinyon-juniper, and one with conifer-oak.

The San Juan National Forest contains a large amount of aspen (A); however, the population sampled was relatively small with only nine samples. The population should be larger to acquire more accurate statistics; nevertheless, as it stands now, the aspen were classified correctly except for one sample which fell into grassland (G). Some of the aspen may have been classified as conifer-aspen (H) or aspen-conifer (E). Past remote sensing studies have shown the classification of aspen from Landsat data to be highly reliable.

Although some grass species are always within the class, wet and mesic grassland (symbol M), all grass is directly associated with and relies greatly upon the season and the amount of annual precipitation. To obtain good statistics on this class, the photographs and Landsat data would have to be recorded within the same month and preferably within the same week. The symbol (M) occurred once as grassland (G).

There were 15 clusters of snow, and all were grouped into the class (X). The only error that occurred was in association with grassland on the south side of the National Forest. There was more snow on the Landsat data taken early in July than on the aerial photography taken in August. Some snow had probably covered what would otherwise be the alpine and bare rock classes.

Oakbrush-conifer (T) was classified accurately 76 percent of the time. The three errors were one with the conifer-oakbrush forest (F) and two with grassland (G).

The conifer-oakbrush forest (F) was found primarily in the western portion of this National Forest. Table 6-3 shows that F was called F eight times. The two classes composed 13 percent of the samples and were not confused with any other classes, although other ADP classes were confused with them.

The class mixed brush (B) was extremely difficult for the photointerpreter to separate. Symbol (B) was called (B) one time. The evaluator was confident of this because that area had been field checked. It was also classified twice as oakbrush and twice as conifer-oakbrush. Not much reliability can be placed on this class.

The remaining class on table 6-3 is cropland (symbol <). Although this was not a class on the statement of work, it was found on the West Image east of the forest. It was confused with grassland and pinyon-juniper one time each and 3 times with conifer-oak within the forest boundary.

The second character of an R2MAP cell is a number 1 to 5. If crown closure is less than 30 percent, the number 1 is assigned to it. If crown closure is 31 to 50 percent, number 2 is assigned. If crown closure is 51 to 70 percent, the number 3 is assigned, and if crown closure is 71 to 100 percent, the number 4 is assigned. If crown closure is not applicable such as with water, rock, soil, snow, and grassland, the number 5 is assigned. An overall PCC for crown closure of 58.7 $\pm$ 4.96 percent is presented in table 5-3. This figure indicates that the PCC is too low for crown closure to be applied to any practical use. Possibly a factor such as crown closure requires a sensor with greater resolution to provide the necessary detail.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The Statement of Work, Division 200, (appendix A) contains the technical specifications for the San Juan National Forest project. In order to assess the overall success of the project effort, a comparison of the requirements with the results is summarized in this section. Recommendations are offered as to use of the products, their potential use for other work, and possible new formats for the data.

The contractor has provided the San Juan National Forest personnel with the following:

a. Classification data tapes are completed, showing the vegetation-cover types in 19 categories subdivided into 50 categories for the East Image and 48 categories for the West Image. These tapes covered all or portions of 85 topographic 1:24 000-scale maps covering the San Juan National Forest. Crown closure was classified into four classes: 0 to 30 percent, 31 to 50 percent, 51 to 70 percent, and 71 to 100 percent for item categories. These tapes are compatible with R2MAP (1:24 000-scale).

   Other classification tapes were made showing the same land features as those previously mentioned. These tapes were in a one cell per pixel format and satisfied the requirements of the contract modification for this project.

b. The area of overlap between Landsat frames was given to the East Image. The Landsat frames were not joined. It was not necessary to join the images because the 1:24 000-scale topographic maps were butt-joined instead of the image. The

results are the same, except that a single quadrangle sheet contains data from only one image. In image butt-joining, a quadrangle sheet could have data from both images, possibly creating a join line down the middle of the sheet. This is the reason two tapes were made. They are referred to throughout this report as the East Image and West Image; however, when the two tapes are written out, they maintain the same form as if they had been butt-joined.

c. No specific alpha-numeric classification printouts of quadrangles were called for by the contracting officers because it was faster and easier to obtain them from the tapes at the Fort Collins Computer Center. The contractor did supply printouts of their choice at the Technical Review meeting in Durango, Colorado, on August 14, 1979. No color coded products were required.

d. This document is the final report which presents the procedures, objectives, and results of preprocessing, processing, postprocessing, and the accuracy of classification. An analysis of the results for cluster identification is included in section 6.

e. All the offload software developed to satisfy the requirements of this contract have been submitted to the USDA. A printout of this program is appendix C of this report.

The accuracy requested in the Statement of Work was 75 PCC with an 85 percent repeatable performance. The 95 percent confidence interval of PCC for overall land feature classes was 71.3 $\pm$ 4.55 percent. The accuracy requested was not achieved if all the land feature categories were kept separate; however, the classification of the combined conifers, combined hardwoods, and combined mixture raised the accuracy to approximately 78.9 $\pm$ 4.1 PCC. A minimum of samples was used in this evaluation process and a continued evaluation of other sites may change the accuracies. Other

problems such as the extending signatures from one terrain type to another, and relabeling misclassified clusters are reported in section 6 of this report.

The 95 percent confidence interval of the overall crown closure accuracies were 58.7 $\pm$ 4.96 PCC and were not acceptable for use. The only reliable crown closure classification was the very dense 71 to 100 percent class represented by the number 4. Landsat was not capable to break out the other crown closures with the desired accuracy.

The Landsat tapes were geometrically corrected (registration-rotation). The RMS error for the East Image was 0.8529 pixels on the X-axis and 0.4838 pixels on the Y-axis. For the West Image, the RMS error was 0.4707 pixels on the X-axis and 0.5203 pixels on the Y-axis. These figures ensure the positional accuracy of the image to the map.

Classification tapes in R2MAP format and an interim report were delivered to San Juan National Forest personnel on March 1, 1979. The final report, along with improved and refined classification tapes, will be delivered on the due date of September 1, 1979.

7.2 RECOMMENDATIONS

The product provided to the San Juan National Forest personnel in the form of classification tapes represents one layer of a data base. The contractor recommends that this layer be kept pure and not be combined with ancillary data on the classification tapes. If ancillary data such as elevation, slope, or aspect are needed, they can be obtained at the data base stage. The classification data is a layer of signatures associated with land cover and a useful tool in achieving the desired results.

It is recommended that a detailed evaluation of the products by the San Juan National Forest personnel, including a full assessment of their value and use, be done as soon as possible. Personnel from all the districts in the National Forest and from different professional disciplines need to evaluate the products for specific purposes in their fields. For example, if a range scientist wanted to study grasses, he may call for all the clusters containing grass and, from these grass clusters, decide what is important and useful to him. A soils scientist may call for all the bare soil, bare rock, and indicator species clusters which are needed in his work. For practical use of the data, make it readily available in the districts and not left in the Supervisors' offices.

The needs of the different professional disciplines in the National Forest and the associated clusters could be arranged on a priority basis. For example, if it were important that all the aspen in the National Forest be included in one cluster, that cluster would undoubtedly have other hardwood types in it. It would, however, include all the aspen in the National Forest, and if this were a priority, the commission error would be allowable. On the contrary, it might be a priority to have a cluster of aspen and nothing but aspen. If this were the case, surely some of the aspen would be lost in the oak, grassland, and aspen-conifer classification. This would be an omission error. Confusion tables that may aid in illustrating these errors are in tables 7-1 and 7-2.

TABLE 7-1.— A HYPOTHETICAL CONFUSION TABLE SHOWING EFFECTS OF OMISSION ERRORS USING ASPEN (A3, A4) AS A PRIORITIZED CLASS

Note: [In this case aspen would be a very pure class but some of the pixels would fall into other similar classes.]

Photographic class	Automatic data processing class							
	H4	H3	E2	A3	A4	03	02	Total
H4	7			1	1			9
H3		10	1	1				12
E2		1	10	6	5			22
A3			2	20	4	3	1	30
A4				2	13	1		16
03				2		8	2	12
02				1		3	6	10
Total	7	11	13	33	23	15	9	111

TABLE 7-2.— A HYPOTHETICAL CONFUSION TABLE SHOWING EFFECTS OF COMMISSION ERRORS USING ASPEN (A3, A4) AS A PRIORITIZED CLASS

Note: [In this case the aspen would probably contain some pixels from classes with similar spectral values.]

Photographic class	Automatic data processing class							
	H4	H3	E2	A3	A4	03	02	Total
H4	7							7
H3		9	1					10
E2		2	12					14
A3				33		2	1	36
A4					23			23
03						11	3	14
02						2	5	7
Total	7	11	13	33	23	15	9	111

With decisions on a priority cluster and if an omission or commission error were acceptable, a modified clustering algorithm is available that will increase the accuracy of a priority cluster. The process used in this procedure begins as a supervised classification. Training fields are located within the cluster and the statistics obtained from the training fields are used as starting vectors in the clustering process. The resulting cluster should provide the user with a more accurate classification of that prioritized land feature.

Another method of obtaining the same prioritized land feature is by delineating or masking-out areas of noninterest. For example, if a user wanted to cluster only the forest, he could mask-out the water with a low reflectance value; and for snow and exposed ground, mask-out with high reflectance values. At this point, processing only the forest clusters would probably result in a more reliable classification.

The National Forest personnel will need to continue to refine labels. As stated earlier in the report, some of the classes such as grass contained several clusters. These clusters, when studied individually, may provide some very useful information. There may be some combinations of clusters and labels that would be helpful. A suggestion is to thoroughly examine a quad sheet from all the different types of terrain in the field, and if necessary, make adjustments in the labeling. Another reason for doing this is because some signatures represent different vegetation in different parts of the forest. The cluster identification tables (5-1A and 5-1B) tell what vegetation dominates the cluster, but there may be some other types within that cluster. While examining quad sheets, it would be worthwhile to check the registration of the Landsat data to the quad sheets.

Another use of Landsat data may be for change detection. This is accomplished by acquiring multiple layers of Landsat data from different years and seasons. If snowfall were of interest, an examination of winter scenes from one year to another would show to what extent down the mountain the snow accumulated and from this, the user could approximate snow quantities. Vegetation trends could be followed, burned-over areas may be tabulated, and regeneration watched. Any number of natural or man-made changes in the forest could be monitored.

In order to make full use of all the computer data bases available and to combine them into useful information, the San Juan National Forest should have someone on their staff who can call up the data and knows the possible uses and flexibilities of the data. Teaching other National Forest personnel would be another responsibility of importance. Much data is available but it provides no benefit unless it is obtained and used.

There are several products that can be created from the classification tapes. First are the alpha-numeric printouts already in hand. The next are color products. They are attractive, easier to use, readily available in different scales and in different size formats, but relatively expensive when compared to the alpha-numeric printouts. It may be desirable to have one done showing the entire forest in the 19 land feature categories for planning purposes and display. It would also be useful to have some of the quad sheets available in color where multiple-use planning is being done. If a certain district desired a classification map of the same categories within its boundaries, it would be easily obtainable.

Too often the tabular data that come with the map data are overlooked. Aside from the heading, the data that are included follow:

a. Plot symbol - only the symbols that represent land features occurring on that quad as shown. This is true unless the user requests only a specified cluster or clusters.

b. Total cells - the total number of cells on the quad from each cluster.

c. Acres - the computer automatically converts cells to acres providing the user with some very useful and timely information.

d. Percent - the percentage of area that cluster covers on the quad sheet.

It is important to make use of all the available data including the tabular data.

While at the Technical Review meeting in Durango, Colorado, the contractor and the review team discussed the possibilities of using formats other than R2MAP. It is recommended that R2MAP data be reformatted to be compatible with the Resource Information Display System (RIDS). This format would have several advantages. First, the RIDS will be maintained by the USDA/Forest Service at a national level; consequently, the user will be freed from the expense and frustrations of maintenance problems. Once in the RIDS format, the user would have access to all the RIDS capabilities such as map overlays, and tabular and plot displays. Also, any data in RIDS will be available. For example, maps of interest on the data base are easily extracted. Additionally, the output could be displayed as line printer or plotted map overlays.

In summary, RIDS formatted data will allow use of all RIDS capabilities and information on the system. Additionally, the user will be spared the expense and problems of system maintenance.

If a change in formats is desirable, this is the time to switch. It would be better to resample the original data than to convert R2MAP directly to RIDS.

The last recommendation to be made by the contractor at this time is to release the data to the public. With this, look for input from other agencies, discuss problem areas and solutions, accept suggestions from within the USDA/Forest Service and from outside. A peer review is a good context for suggestions. Search for opportunities to present the work that has been done in symposiums, in professional papers, and any other media that may be available. The video tapes already in progress are an excellent beginning.

The San Juan National Forest personnel have been provided with a layer of data through this contract that sets them far ahead in remote sensing of any other National Forest in the region. Hopefully, the data will be used in many varied ways.

APPENDIX A

STATEMENT OF WORK

SPECIFICATIONS

DIVISION 100 - GENERAL SPECIFICATIONS

110 - Scope of Contract

The work will consist of mapping vegetation cover types on the San Juan National Forest and on lands administered by the San Juan National Forest, headquarters at Durango, Colorado.

111 - Projects

The purpose of this project is to develop vegetation cover type maps via classification of the most appropriate landsat (Land Satellite) data. These data (latest good quality, summer landsat data) will be classified by ADP (Automatic Data Processing Techniques) and the resulting classification tapes must be formated to be compatible with R2MAP. (See Exhibit C for description of R2MAP). The products must be acceptable from the standpoint of accuracy as specified in 300 Inspection and Acceptance.

120 - Description and Location

The attached map, Exhibit A, shows the location of areas to be classified.

121 - General Description and Detailed Unit Information of the Work Area. The designated area is a very heterogeneous range of mountains that includes 11 primary ecological subdivisions--foothills, pine bunchgrass, shrub, coniferous, mountain bunchgrass, aspen grass, aspen weed, mountain meadows, alpine, prairie grassland (sandlands and prairie grassland (hardlands).

130 - Government Furnished Property. Any or all remote sensing products from prior inventories (Hoffer and Krebs), any presently existing inventory data, and other ancillary data can be provided to the Contractor at the cost for reproduction. The San Juan will provide up to two man-weeks of assistance in developing training field signatures, and evaluation criteria.

140 - Contractor Furnished Property. All landsat data, tapes and composites must be furnished by the Contractor. All machine processing time, output product development, as well as field personnel for training and evaluation, must be provided by the Contractor.

Large scale color aerial photos (1:15,840) of the Forest can be made available on a loan basis. Small scale 1:120,000 and 1:60,000 color or color infrared photography NASA-1973 can be purchased by the Contractor as needed for training and evaluation.

150 - Minimum Qualifications. The Contractor must demonstrate his capability in Automatic Data Processing of Landsat Data and must be able to meet the accuracy criteria and time frame for completion as stated in this IFB. Offerors must submit, with their offer, a summary of their capability and experience in this field.

DIVISION 200 - TECHNICAL SPECIFICATIONS

210 - Product Requirements. The Contractor shall provide the San Juan National Forest with the following items:

1. Classification data tapes showing the vegetation cover types in 18 categories (see Exhibit A) for approximately 61 - 7-1/2' quadrangles over the San Juan NF (see Exhibit B). Crown closure will be classified in four classes; 0 - 30%, 31 - 50%, 51 - 70%, and 71 - 100%; for item categories 1 through 11 on Exhibit A. These tapes must be compatible with R2MAP (1:24,000 scale) (see Exhibit C, R2MAP).

2. Alpha numeric classification printouts at 1:24,000 scale for approximately (61) 7-1/2' quads over the San Juan National Forest. No color coded products are required.

3. Final report showing the procedures used include preprocessing, processing, post processing, and the accuracy of classification (PCC - Probability of correct classification). A summary and conclusion is also required, along with the total number of acres classified into each feature category within the Forest boundary.

4. All software developed to satisfy the requirement of this contract will become the property of U.S. Department of Agriculture.

220 - Product Accuracy

1. The lowest overall classification performance must be 75% with a high degree of repeatability. In cases of extreme misclassification, less than 50% accurate, which may occur in category item numbers 1 and 2, and 5 and 6, a combination of features is acceptable. This feature combination must be explainable and proof shown that the original feature separation was attempted. (See Exhibit A for definitions.)

2. The landsat tapes must be geometrically corrected (Registration - Rotation), RMS error of less than 1.0 is required to insure positional accuracy.

230 - Delivery Schedule

Classification tapes in R2MAP format and an interim progress report must be provided to the San Juan by March 1, 1979. This is an interim product and does not require a complete evaluation of results. The final report must be provided to the San Juan by August 15, 1979.

DIVISION 300 - INSPECTION AND ACCEPTANCE

Quality control will be maintained through review of the interim report and PCC estimations provided by the Contractor. The Forest Service reserves the right to visit the Contractor as a part of progress review, and to field check classification accuracies to insure accuracy standard compliance.

DIVISION 400 - PAYMENT

Partial payment to the Contractor upon delivery of the classification data tapes to the San Juan. Final payment will be made to the Contractor upon delivery of the final report and alpha numeric products.

EXHIBIT A

Vegetation and Ground Cover Type Categories and Definitions

1. Spruce/Fir Forest - Mixed coniferous spruce and fir timber stands with less than 30% other tree species, based on crown density.

2. Douglas fir/White Fir Forest - Mixed coniferous Douglas fir/white fir timber stands with less than 30% of other tree species, based on crown density.

3. Ponderosa Pine Forest - Ponderosa pine timber stands with less than 30% of other tree species, based on crown density.

4. Pinon/Juniper Forest - Mixed coniferous pinon/juniper - timber stands with less than 30% other tree species, based on crown density.

5. Coniferous/Aspen Forest - Mixed stands of coniferous tree species and aspen with 30-50 percent aspen, based on crown density.

6. Aspen/Coniferous Forest - Mixed stands of coniferous tree species and aspen with 30-50 percent coniferous species, based on crown density.

7. Aspen Forest - Aspen timber stands with less than 30 percent other tree species, based on crown density.

8. Coniferous/Oakbrush Forest - Coniferous forest stands with 30-50 percent oakbrush, based on crown density.

9. Oakbrush/Coniferous Forest - Oakbrush stands with 30-50 percent coniferous tree species, based on crown density.

10. Oakbrush - Oakbrush stand with less than 30 percent other brush species, based on crown density.

11. Mixed Brush - Brush stands with 30 percent or more brush species other than oakbrush, based on crown density.

12. Wet and Mesic Grassland - Areas dominated by grasses and other herbaceous plants requiring constant water availability.

13. Grassland - Areas dominated by grasses and other herbaceous plants.

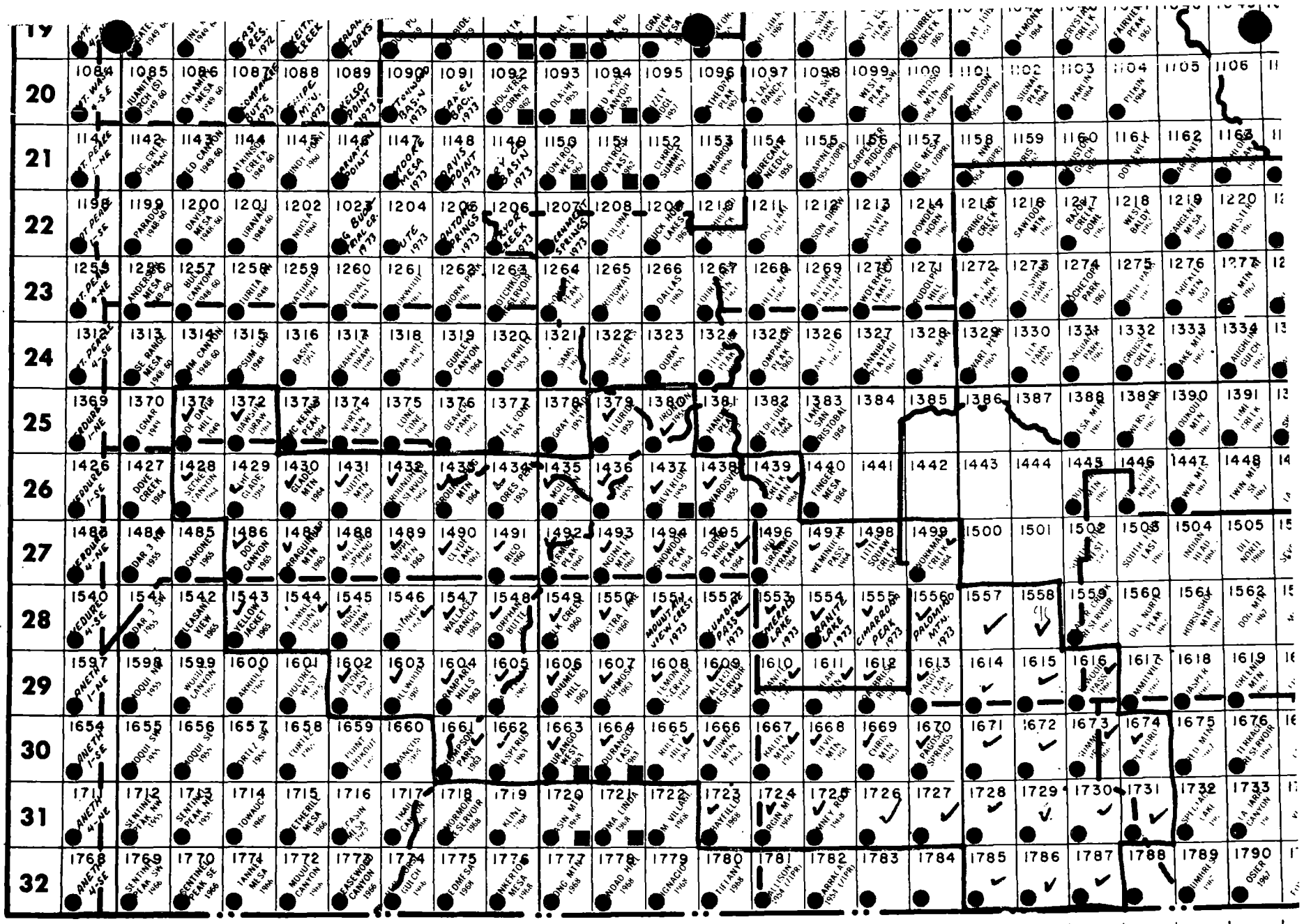
14. Rocky Grasslands - Areas dominated by grasses and other herbaceous plants where rock or rocky areas comprise at least 50 percent of the area.

15. Alpine - Areas above timerline covered primarily by vegetation. These areas may have rocky areas interspersed.

16. Willow - Areas where willow species dominate, usually along drainages, in low wet areas or adjacent to areas of snow accumulation.

17. Bare Rock - Areas of bare rock or soil which is essentially devoid of vegetation.

18. Water - Areas covered by a body of water during the fall which are a minimum of three acres in size.



A-6

✓ Quads furnished

APPENDIX B

RSAL FACILITY

A.5 IMAGE PROCESSING AND ADP ANALYSIS FACILITIES

The Remote Sensing Applications Laboratory (RSAL) is Lockheed's newly-established data processing facility. The experience gained by our scientists in supporting NASA/JSC remote sensing efforts went into the procurement and the configuration of RSAL's systems. The laboratory is an independent, self-contained research facility devoted expressly to development and application of remote sensing technology. The laboratory includes state-of-the-art automatic data processing hardware, specialized image processing software, photointerpretation and mensuration instruments, and other supporting equipment. The processing system, featuring a PDP 11/70 central processing unit, an AP 120B array processor and a Comtal Vision I interactive display console, is presented in schematic form in Figure A-1. The laboratory is able to provide a complete integrated systems approach to remote sensing technology in support of energy, hydrology, land use, meteorology and forestry studies.

Within the laboratory, data from satellite, aircraft, field, and archival sources can be acquired, screened, analyzed, and used to produce final products tailored to the specific user's needs. These applications data products can be in the form of maps, photomosaics, thematic overlays, annotated imagery, reports, workships, training sessions, or consultations. On the other hand, specific procedures and software can be developed for certain applications and these procedures and software, together with products, can be transferred to the customer for installation on their own data processing system.

The following two sections (A.5.1 and A.5.2) describe in rather general terms the hardware and software aspects of RSAL. Paragraph A.5.3 provides additional general descriptions.

A.5.1 RSAL Image Processing System Hardware Description

The hardware available for interactive, batch, as well as real time developmental data processing work, is described below.

- PDP 11/70 Multi-function Data Processing System with Floating Point Processor and 256K byte main memory.
- Floating Point System, Inc.'s AP 120B Array Processor with an extensive library of math routines.
- Xerox Versatec 1110A Electrostatic Printer/Plotter with 1000 lines per minute printing speed.

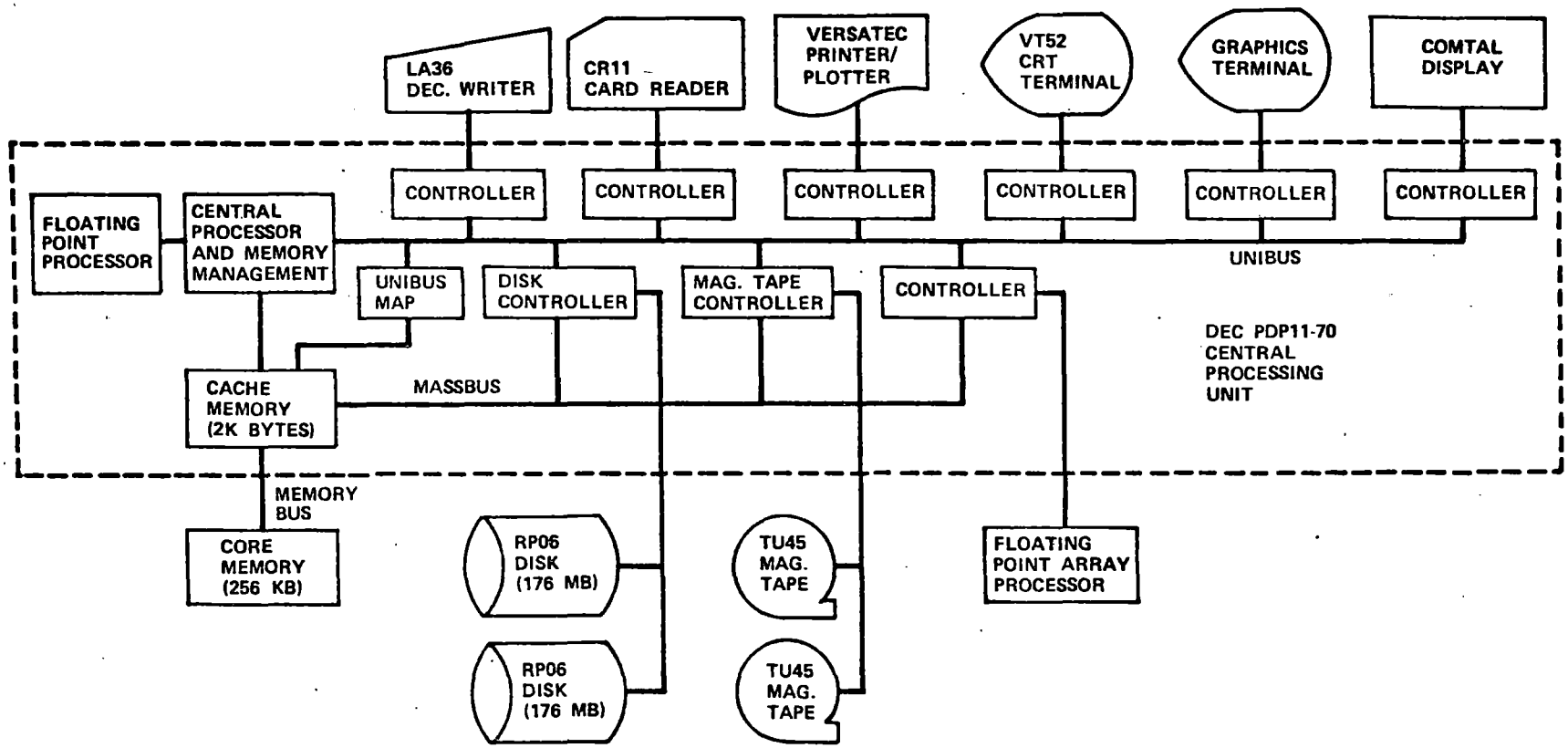


Figure A-1. Functional block diagram of Lockheed's Remote Sensing Applications Laboratory system.

- Two DEC RP06 Disk Units each with 174 M/byte storage capacity.
- Two DEC TU45 9 track magnetic tape unit.
- DEC CR-11 Card Reader that reads 285 cards per minute.
- DEC VT-52 CRT Terminal.
- DEC LA-36II DECWriter Operations Console.
- Tektronix 4012 Graphic Terminal.
- Comtal Vision-1 Interactive Image Analysis System. This is a complete image processing system providing the user with built-in interactive processing and control capabilities. The system produces a high spatial resolution video image over a full range of brightness levels in shades of gray, pseudo-color or full color. The Vision-1 System consists of an integrated LSI-11 microprocessor with 16K read only memory, 1 high resolution color monitor, application firmware, 5 image refresh memories and 8 graphics (thematic) plane refresh memories. The spatial resolution of each refresh memory is 512 pixels × 512 lines. Every pixel is visible on the display. Image brightness resolution is 8 bits. Each image refresh has fully independent function processing (look-up table) which may be used for contrast stretch. Each function memory is 256 cells, each cell 8 bits. When function memory is applied to the display the 8-bit reflectance value of the refresh memory image is used as an address into the function memory table. The value stored in the function memory at that address determines the contrast of the displayed image.

  Any three of the image refresh memories may be assigned to any of the three color display channels (red, blue or green) for a color presentation of the image. The color presentation may be with, or without, all three function memories applied.

  In addition, one refresh image at a time may be displayed with color slicing via the pseudo-color memory. The pseudo-color memory is also a table look-up type memory. It is 256 cells, each cell 12 bits. Each 12 bit cell is divided into 4 bits each for the colors green, red and blue.

A.5.2 RSAL Image Processing System Software Description

a. Design Concept

The primary objective was to build a very flexible subsystem while making it very easy to use and modify. The system

provides tools for image processing in the areas of interactive color displays, classification (supervised and unsupervised), image enhancement, geometric correction, spatial and spectral transformation, and many others. A researcher may develop his own software and tie it into the main line without modifying the standard subsystem.

The software for the interactive portion of the Image Processing Subsystem consists of a set of programs controlled by an "executive" routine and executed interactively with, in some instances, both a foreground and a background program executing concurrently. LEX, the Lockheed EXecutive, is a simple and flexible executive which allows a Logical Subsystem of related tasks under operator control. LEX is two-level, menu-driven, and designed to operate in conjunction with a Tektronics 4012 terminal. LEX allows up to 10 Master Menu entries each of which may have up to 10 Sub-Menu entries. The current system software will be discussed later in this section. The batch portion of the subsystem is a set of programs offering the same image processing functions as the interactive portion (except for the COMTAL displays) but executed in batch mode.

b. Software Description

IAS (Interactive Applications System). IAS is a DEC provided multifunction operating system which supports the concurrent execution of three processing modes: interactive, batch, and real-time. Real-time applications operate on a priority basis, while interactive and batch tasks are time-shared.

Real-time Applications. These capabilities are designed for applications that require response to physical events as they occur.

Interactive Processing. Operating from an interactive terminal, each user may create and run programs interactively or submit them to a batch stream; alternately, the user may exploit other user's programs or standard programs provided by the system. Even though many users benefit from sharing programs and files, the system preserves the individual user's privacy and shields the activities of other users.

Batch Processing. Under IAS, programs can be created and tested interactively, and then submitted to a batch stream for execution. In batch mode, programs can be compiled or assembled, linked, and executed; devices can be opened and closed, and messages can be issued to the operator. An interactive user may create a file of batch commands and submit the file to a batch stream; alternatively the batch job could be submitted on cards.

Current Lockheed Executive Processor. Executive menus for the current image processing system consist of:

Level I Menus

D Data Load/Preprocess

T Training/Classification

Output Products/Reports

Level 2 Menus

D Data Load/Preprocess

1. Image Tape to Disk
2. Image Display
3. Merge Image File
4. Mosaic Image File
5. Geometric Corrections of Image Files

T Training/Classification

1. Field Definition
2. Statistics Computation
3. Mixture Density Classifier
4. Load Map to Themes
5. Display Categories/Subclasses
6. Iteractive Clustering
7. Affine/Ratio Transformation

O Output Products/Reports

1. Field Report
2. Statistics Report
3. Field Definition File Edit
4. Map File to Tape
5. Map File to Printer
6. Refresh Memory Save
7. Image Header Report/Modify
8. Comtal Tables Save/Restore
9. Image File to Tape
10. Histogram Print

Some highlights of the system processors are described by the following:

- Merge Image Files. This processor allows the analyst to select two image files and merge them by channel into one output image file. The analyst may specify all channels or selected channels from each of the input files. The selected channels from file 1 will precede the selected channels from file 2 on the output file. The output file will contain the same number of pixels as the input file with the fewer pixels and the same number of scans as the input file with the fewer scans.

- Mosaic Image Files. This processor allows the analyst to select two image files and mosaic them, either side by side or end to end, into one output file. The analyst may specify all channels or selected channels from the input files, but the number of channels chosen for each file must be equal.

  The side by side mosaicked file will contain in channel 1 the pixels from the first selected channel of file 1 followed by the pixel from the first selected channel of file 2. The other output channels are created following the name convention. The output file will contain the same number of scans as the input file with the fewer scans. The number of pixels per scan for the output file will be the sum of the number of pixels per scan on files 1 and 2.

  The end to end mosaic will produce an output file containing all the chosen pixels for all selected channels and all scans from file 1 followed by all the chosen pixels from file 2. The final output file will contain the same number of pixels per channel per scan as the input file with the fewer number of pixels per scan. The number of scans for the output file will be the sum of the number of scans from files 1 and 2.

- Band Ratioing. Band ratioing is an image enhancement technique which may be used to enhance certain geologic and vegetation features in an image. Ratioed images reduce or eliminate differences in images due to illumination or atmospheric factors such as haze. True differences in reflectivity in two different bands are emphasized in the ratioed image.

  This program allows three types of image transformations - either affine transformation, ratio transformation, or log ratio transformation. The transformed image is optionally scaled to a 0 to 255 range and saved on disk.

- Geometric Correction. This program allows scaling, rotation and translation to be performed on an image file for corrections of geometric distortions. A first order bivariate polynominal with six coefficients is input as the model for the distortion. The coefficients are obtained using the least square procedure between two sets of control points, one from the distorted image and the other from a map projection or an undistorted image.

- Iterative Clustering. This program implements an algorithm which sorts a given set of multivariate data points into similar groups or clusters. The clustering procedure is an iterative procedure which assigns each sample (pixel) to a specific cluster by determining the nearest cluster center and assigning the sample to it. After the user has input all his parameters, a printer report is produced. At the completion of clustering, a statistics file containing cluster means, standard deviations, and covariance matrices is written, and can be printed by running the 'Statistics Report Program'. Also at the completion of clustering a cluster map file is produced and can be displayed on the COMTAL by using the programs 'Load-Map to Themes' and 'Display Categories/Subclasses'.

c. Programming Languages

IAS supports several programming languages, including BASIC, COBOL, FORTRAN-IV and MACRO-11. The MACRO-11 Assembler is the standard IAS language, whereas translators for the other languages are optional. FORTRAN FOUR PLUS and MACRO-11 are presently implemented in the RSAL. Others may be implemented as the need occurs.

FORTRAN. The FORTRAN (FORmula TRANslation) language is especially useful in scientific and mathematical applications. PDP-11 FORTRAN FOUR PLUS conforms to the specifications of American National Standard FORTRAN (X3.9-1966), with substantial extensions to that standard. The FORTRAN system consists of a compiler, a library of functions, and an object time system (OTS). The compiler produces object code from the source program. The OTS consists of routines that are selectively linked with the user's program to perform certain arithmetic, I/O, and system-dependent service operations. The OTS also detects and reports run-time error conditions.

MACRO-11. The programmer who wishes to work closely with the PDP-11 hardware and IAS may use the powerful MACRO-11 assembler. In addition to allowing the user to invoke machine-language instructions, MACRO-11 allows the programmer to define "macros" which may be invoked to generate repetitive coding sequences. The MACRO-11 language can be used both in interactive and batch processing applications.

A.5.3 Additional General Descriptions

a. Versatec 1110A Printer/Plotter

The Versatec 1110A Printer/Plotter is supported under the IAS operating system by the Versa plot V07 Electrostatic Plotting Software (EPS) package. This package includes the basic pen plotter calls (PLOT, PLOTS, SYMBOL, LINE, etc.) for compatibility with conventional pen plotter software. The package also includes an extended background grid capability, as well as an area computation capability. Other features of EPS include multiple sector processing algorithms, automatic expanded plot stripping, variable line width, selection, and expanded plotting area selection.

In addition to the EPS package, the Gray Scale Software (GSS) package is available for the Versatec. This GSS package offers a halftone plot capability with thirty-two gray levels, image enhancement, enlargement, editing, and positioning. The Versatec 1110A supports the ASCII 96-character set.

b. Tektronix 4012 Graphic Terminal

The Tektronix 4012 Graphic Terminal is supported under IAS by the standard DEC TT handler and a library of FORTRAN IV subroutines called the Plot 10 Terminal Control System (TCS). Included in the library are routines for (a) multigraph windowing and superimposing, (b) automatic data scaling, clipping, rotating, and zooming, (c) selectable coordinate systems and line modes (dashed, solid), and (d) alphanumeric formatting control. Also included in the RSAL Graphic Support packages is the PLOT 10 Preview library which offers CALCOMP compatible capabilities.

c. AP-120B Array Processor

The AP-120B Array Processor is supported under IAS by the Array Processor Executive (APEX) version 2.0. APEX 2.0 is designed to queue user calls to the AP-120B to support multiuse activity, although no memory protection/user program restoration facilities are incorporated into the handler.

Four support programs are available for AP software development: (1) AP Assembly Language (APAC) – a cross-assembler for producing AP-120B internal code from a symbolic coding language; (2) AP Linker (APLINK) – a program for linking and relocating APAL object modules into a single executable load module; (3) AP Simulator (APSIM) – a program which simulates the AP-120B on an off-line basis for producing equivalent run-time characteristics and floating point arithmetic simulations; and (4) AP Hardware Debugger (HWDBUG) for testing and debugging new programs for the AP-120B.

The AP-120B is further supported by a math library of over 150 program routines, such as vector add, FFT, complex vector

multiply, matrix inverse, ect. These routines are callable from FORTRAN, assembly language, or the array processor assembly language.

d. COMTAL Vision-1 Software

The following highlights the system environment for the Comtal Vision-1 software. Data in the forms of video, theme, target and annotation can simultaneously be displayed. Video (or image) data can be scrolled, histogramed, equalized, linearized, smoothed, differenced, zoomed, etc.

APPENDIX C
PROGRAM COMPILATION FOR THE R2MAP OFFLOAD PROGRAM SJNF

SJNF.FTN /TR:BLOCKS/WR

```
0001            PROGRAM SJNF
                C
                C     A QUICK AND DIRTY (SEE MARVIN RADER) TO CONVERT A VIDEO IMAGE
                C     DISC FILE FROM THE PDP 11/70 TO A FIELD DATA COBOL COMPATIBLE
                C      MAG TAPE TO BE PROCESSED ON THE UNIVAC 1100 X8 SYSTEM..
                C
                C    TAPE CHARACTERISTICS     1600 FPI   ...  9 TRK...ODD...UNLABELED..
                C    COBOL CHARACTERISTICS....
                C         BLOCKED 20   272 CHARS PER RCD
                C
                C          V A R I A B L E     D E F N
                C
                C    FNAM= FILE NAME OF VIDEO IMAGE
                C     NCIFN=NUMBER OF CHARS IN FILE NAME
                C      FCB=FILE CONTROL BLOCK
                C     VIDEO=1 SCAN LINE OF VIDEO DATA (CLASSIFIED)
                C    HDR=COBOL HEADER(ALSO TRAILER)
                C    LIP=LOGICAL INPUT UNIT ONE  DISC FILE
                C    LOP=LOGICAL OUTPUT  (TAPE UNIT)
                C    NLINS=NUMBER OF LINES OF THE VIDEO UNIT TO PROCESS
                C    EF=
                C    ERR=ERROR FLAG FOR FIELDO AND R
                C    SYMBOL=CLUSTER CHARACTER IDS FOR RESPECTIVE CLASSES (COMMON CLASS)
                C
                C
0002              IMPLICIT INTEGER (A-Z)
0003               COMMON/CLASS/SYMBOL(32),IDBUG,IXLATE
0004              BYTE          FCB(512),VIDEO(512),HDR(168),
                & FD(282,20),TAPE(213,20),FDLO(5646)
0005             EQUIVALENCE(FDLO(7),FD(1,1))
0006              BYTE FNAM(12,100)
0007               REAL PQUAD(100)
0008              HDRWDS=63
0009              READ=1
0010               ERR=0
0011              LIP=1
0012               LOP=2
0013               NLINS=0
0014             PDPWDS=2120
0015               EF=21
0016              NQUADS=0
0017               WRITE(6,600)
0018    600       FORMAT('1'///,T50,'PROGRAM SJNF'//
                & T10,'CONVERT VIDEO IMAGE (PDP11/70 TO COBOL (UNIVAC1100)',
                & ' MAG TAPE'///)
0019               WRITE(6,603)
0020    603       FORMAT(' ENTER AVAILABLE DRIVE FOR O/P TAPE: ')
0021               READ(5,501) MTU
```

```
0022             CALL MTINIT(LOP,MTU)
0023            WRITE(6,608)
0024    608     FORMAT(' ENTER A NON ZERO INTEGER FOR DBUG PRINT: ')
0025            READ(5,501) IDBUG
0026             WRITE(6,602)
0027    602      FORMAT(' ENTER NUMBER OF LINES TO PROCESS: ')
0028             READ(5,501) NLINS
0029    501      FORMAT(I8)
0030             IF(NLINS .LE. 0) GO TO 9999
0031            LAST=NLINS-((NLINS/20)*20)
0032             WRITE(6,615)
0033    615     FORMAT(' ENTER A NON ZERO DIGIT TO LIST NON XLATING PIXELS: ')
0034             READ(5,501) IXLATE
0035             WRITE(6,666) MTU,IDBUG,NLINS,IXLATE
0036    666     FORMAT(' MTU,IDBUG,NLINS,IXLATE=',4I4)
0037               CALL COBHDR(HDR,IDBUG)
0038               CALL MTWRIT(LOP,HDR,HDRWDS)
0039               CALL MTEOF(LOP)
0040    1       CONTINUE
0041             NQUADS=NQUADS+1
0042            WRITE(6,601)
0043    601     FORMAT(' ENTER VIDEO IMAGE FILE NAME - CTL Z TO TERMINATE: ')
0044            READ(5,500,END=9999) (FNAM(L,NQUADS),L=1,12)
0045    500      FORMAT(12A1)
0046             WRITE(6,667) (FNAM(L,NQUADS),L=1,12)
0047    667     FORMAT(' PROCESSING FILE: ',12A1)
0048             NCIFN=0
0049             DO 300 L=1,12
0050             IF(FNAM(L,NQUADS) .EQ. ' ') GO TO 301
0051             NCIFN=L
0052    300      CONTINUE
0053    301      CONTINUE
0054             IF(NCIFN .EQ. 0) GO TO 9999
0055            WRITE(6,611)
0056    611     FORMAT(' ENTER QUAD NO - 4 CHARS, RIGHT JUSTIFIED: ')
0057            READ(5,502) PQUAD(NQUADS)
0058    502     FORMAT(A4)
0059            CALL FIELDO(LIP,READ,FNAM(1,NQUADS),NCIFN,ERR,EF,FCB)
0060             IF(ERR .GE. 0) GO TO 10
0061            WRITE(6,604) ERR,(FNAM(L,NQUADS),L=1,12)
0062    604     FORMAT(' FIELDO ERR=',I4,' FILE=',12A1,'  ** ABORT **')
0063            GO TO 8888
0064    10        CONTINUE
0065             IF(IDBUG .NE. 0) WRITE(6,609) (FNAM(L,NQUADS),L=1,12),
          &  (FCB(LL),LL=1,112)
0066    609      FORMAT(///' FCB DUMP FOR FILE: ',12A1//' ',12(O3,1X))
0067           BCNT=0
0068             CHNL=1
```

```
0069            FRSPIX=1
0070           LSTPIX=130
0071          BUFSIZ=134
0072            II=0
0073            CALL COBCTL(PQUAD(NQUADS),FDLO,1)
      C  $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
      C
      C       THIS (LOOP 100) IS THE MAJOR SCAN TRANSLATE LOOP
      C
      C $$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
0074            DO 100 I=1,NLINS
0075            II=II+1
0076            SCANNO=I
0077            CALL FIELDR(LIP,SCANNO,CHNL,FRSPIX,LSTPIX,VIDEO,BUFSIZ,
     & FCB,ERR)
0078            IF(ERR .EQ. 0) GO TO 11
0079           WRITE(6,606) ERR,SCANNO,(FNAM(L,NQUADS),L=1,NCIFN)
0080    606    FORMAT(' FIELDR ERR= ',I4,' RCD= ',I4,' FILE: ',12A1)
0081           GO TO 8888
0082    11      CONTINUE
0083           IF(IDBUG .NE. 0) WRITE(6,968) SCANNO,(VIDEO(L),L=1,130)
0084    968    FORMAT(/' I/P RECORD: ',I3/' ',10(1X,O3))
0085          MOD20=II-(((II-1)/20)*20)
0086           CALL ROWNO(SCANNO,FD(1,MOD20),16)
0087           CALL XLATE(VIDEO,1,130,FD(1,MOD20),19)
0088           IF(IDBUG .NE. 0) WRITE(6,969) (FD(L,MOD20),L=1,130)
0089    969    FORMAT(' XLATED VIDEO..'/' ',10(1X,O3))
0090           IF(IXLATE .EQ. 0) GO TO 97
0091            DO 96 K=19,278,2
0092             IF(FD(K,MOD20) .NE. '?') GO TO 96
0093           PIX=(K-18)/2+1
0094            WRITE(6,614) SCANNO,PIX,(FNAM(L,NQUADS),L=1,NCIFN)
0095    614    FORMAT(' ** XLATE FAIL -- ON SCAN ',I3,' PIX ',I3,' FILE ',
     & 12A1,'  ?? INSERTED')
0096    96     CONTINUE
0097    97     CONTINUE
0098             IF(MOD20 .NE.20) GO TO 100
0099    777     CONTINUE
0100            DO 99 J=2,20
0101            DO 99 K=1,15
0102             FD(K,J)=FD(K,1)
0103    99      CONTINUE
0104          CALL PACK(FDLO,5646,TAPE)
0105           CALL MTWRIT(LOP,TAPE,PDPWDS)
0106          BCNT=BCNT+1
0107           II=0
0108    100      CONTINUE
```

```
      C $$$$$$$$$$$$$$$$$$$$$$$$
      C
0109            CALL FIELDC(LIP)
0110           IF(LAST .EQ. 0) GO TO 1
0111            LAST=0
0112            GO TO 777
0113    9999   CONTINUE
0114            CALL MTEOF(LOP)
0115          CALL COBEOF(HDR,IDBUG,NLINS,BCNT)
0116            CALL MTWRIT(LOP,HDR,HDRWDS)
0117            CALL MTEOF(LOP)
0118             CALL MTRWD(LOP)
0119             CALL MTRLSE(LOP)
0120    8888     CONTINUE
0121           WRITE(6,612)
0122    612    FORMAT('1'///10X,'THE FOLLOWING FILES WERE PROCESSED: '
     &  ///10X,'FILE NAME',5X,'QUAD NO'/)
0123           N=NQUADS-1
0124            DO 775 I=1,N
0125           WRITE(6,613) I,(FNAM(L,I),L=1,12),PQUAD(I)
0126    613    FORMAT(' ',I3,7X,12A1,5X,A4)
0127    775     CONTINUE
0128             STOP
0129            END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	003302	865	RW,I,CON,LCL
2	$PDATA	000024	10	RW,D,CON,LCL
3	$IDATA	001576	447	RW,D,CON,LCL
4	$VARS	030720	6376	RW,D,CON,LCL
5	$TEMPS	000004	2	RW,D,CON,LCL
6	CLASS	000104	34	RW,D,OVR,GBL

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
BCNT	I*2	4-030666	BUFSIZ	I*2	4-030676	CHNL	I*2	4-030670	EF	I*2	4-030650	ERR	I*2	4-030636
FRSPIX	I*2	4-030672	HDRWDS	I*2	4-030632	I	I*2	4-030702	IDBUG	I*2	6-000100	II	I*2	4-030700
IXLATE	I*2	6-000102	J	I*2	4-030714	K	I*2	4-030710	L	I*2	4-030660	LAST	I*2	4-030656
LIP	I*2	4-030640	LL	I*2	4-030664	LOP	I*2	4-030642	LSTPIX	I*2	4-030674	MOD20	I*2	4-030706
MTU	I*2	4-030654	N	I*2	4-030716	NCIFN	I*2	4-030662	NLINS	I*2	4-030644	NQUADS	I*2	4-030652
PDPWDS	I*2	4-030646	PIX	I*2	4-030712	READ	I*2	4-030634	SCANNO	I*2	4-030704			

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
FCB	L*1	4-013016	001000	256	(512)
FD	L*1	4-000006	013010	2820	(282,20)
FDLO	L*1	4-000000	013016	2823	(5646)
FNAM	L*1	4-025532	002260	600	(12,100)
HDR	L*1	4-015016	000250	84	(168)
PQUAD	R*4	4-030012	000620	200	(100)
SYMBOL	I*2	6-000000	000100	32	(32)
TAPE	L*1	4-015266	010244	2130	(213,20)
VIDEO	L*1	4-014016	001000	256	(512)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
1	1-000552	10	1-001340	11	1-001770	96	1-002516	97	1-002542
99	**	100	1-002712	300	**	301	1-001070	500'	3-000552
501'	3-000332	502'	3-000664	600'	3-000000	601'	3-000454	602'	3-000264
603'	3-000136	604'	3-000670	606'	3-001014	608'	3-000206	609'	3-000744
611'	3-000606	612'	3-001260	613'	3-001372	614'	3-001156	615'	3-000336

666' 3-000426 667' 3-000556 775 ** 777 1-002560 968' 3-001064
969' 3-001122 8888 1-003056 9999 1-002770

FUNCTIONS AND SUBROUTINES REFERENCED

COBCTL COBEOF COBHDR FIELDC FIELDO FIELDR MTEOF MTINIT MTRLSE MTRWD MTWRIT PACK ROWNO XLATE

TOTAL SPACE ALLOCATED = 036154 7734

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
      C         BLOCK DATA SJCLASS
0001            BLOCK DATA
      C
      C     BLOCK DATA TO DEFINE THE CLUSTER SYMBOLS FOR TRANSFER TO THE
      C    SAN JUAN N. F. COBOL TAPE....
      C      SYMBOL CORRESPONDENSE OBTAINED FROM GERALD ARP..
      C
0002             DOUBLE PRECISION SYMBOL(8)
0003            COMMON/CLASS/SYMBOL,IDBUG
      C
      C        CLUSTER MAP.....SYMBOL 1 CORRESPONDS TO CLUSTER 1,
      C       SYMBOL 2 TO CLUSTER 2,...,SYMBOL A TO CLUSTER 10,...ETC
      C
0004             DATA SYMBOL/'12345678','9ABCDEFG','HIJKLMNO',
     &  'PQRSTUVW','XYZ0@*[ ]','#()-+=<&','$%:?!,^','";.←↑↑← -'/
0005             DATA IDBUG,IXLATE/0,0/
0006             END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
4	$VARS	000002	1	RW,D,CON,LCL
6	CLASS	000102	33	RW,D,OVR,GBL

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
IDBUG	I*2	6-000100	IXLATE	I*2	4-000000									

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
SYMBOL	R*8	6-000000	000100	32	(8)

TOTAL SPACE ALLOCATED = 000104 34

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
0001              SUBROUTINE COBHDR(HDR,IDBUG)
0002             IMPLICIT INTEGER (A-Z)
0003             BYTE HDR(1)
0004             REAL*8 A(21)
0005             DATA A/'HDRS@@@I','!@@,@@@@','@@@@@@@@','[ZJ@@@@@',
          & '@@@[@@@@','@@@@@@@@','@@@@@@@@','@2@@@@@@','@@@@@@@@',
          & '@@@@@@@@','@@@@SAN ','JAUN NAT','IONAL FO',
          & 'REST PDP','11/70 VI','DEO IMAG','E - TRAN','SLATED B',
          & 'Y W.V. A','RGO/LEC ','JAN 1979'/
0006             CALL ASC2FD(A,1,168,HDR,1)
0007             IF(IDBUG .NE. 0) WRITE(6,601) (HDR(L),L=1,168)
0008    601      FORMAT(' COBOL HDR BEFORE PACK..AFTER XVERT'//
          & ' ',12(03,1X))
0009             CALL PACK(HDR,168,HDR)
0010             IF(IDBUG .NE. 0) WRITE(6,600) (HDR(L),L=1,168)
0011    600      FORMAT(///'  COBOL HEADER AS WRITTEN TO TAPE....'//
          & ' ',12(03,1X))
0012              RETURN
0013              END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	000276	95	RW,I,CON,LCL
2	$PDATA	000010	4	RW,D,CON,LCL
3	$IDATA	000206	67	RW,D,CON,LCL
4	$VARS	000252	85	RW,D,CON,LCL

ENTRY POINTS

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
COBHDR		1-000000												

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
IDBUG	I*2	F-000004*	L	I*2	4-000250									

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
A	R*8	4-000000	000250	84	(21)
HDR	L*1	F-000002*	000001	0	(1)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
600'	3-000062	601'	3-000000						

FUNCTIONS AND SUBROUTINES REFERENCED

ASC2FD PACK

TOTAL SPACE ALLOCATED = 000765 251

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
0001          SUBROUTINE COBEOF(HDR,IDBUG,NL,BC)
0002          IMPLICIT INTEGER (A-Z)
0003          BYTE HDR(1)
0004          REAL*8 A(21)
0005          DATA A/'EOFS@@@I',' !@@,@@@@','@@@@@@@@','[ZJ@@@@@','@@@[@@@@',
             1 '@]@@@@@@',15*'@@@@@@@@'/
0006          CALL ASC2FD(A,1,168,HDR,1)
0007          HDR(16)=IAND(BC/"10000,15)
0008          HDR(17)=IAND(BC/"100,63)
0009          HDR(18)=IAND(BC,63)
0010          HDR(22)=IAND(NL/"10000,15)
0011          HDR(23)=IAND(NL/"100,63)
0012          HDR(24)=IAND(NL,63)
0013          IF(IDBUG.NE.0)WRITE(6,601)(HDR(L),L=1,168)
0014    601   FORMAT(' COBLO EOF BEFORE PACK..AFTER XVERT'//
             1 ' ',12(O3,1X))
0015          CALL PACK(HDR,168,HDR)
0016          IF(IDBUG.NE.0)WRITE(6,600 )(HDR(L),L=1,168)
0017    600   FORMAT(///' COBOL EOF AS WRITTEN TO TAPE....'//' ',12(O3,1X))
0018          RETURN
0019          END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	000442	145	RW,I,CON,LCL
2	$PDATA	000010	4	RW,D,CON,LCL
3	$IDATA	000202	65	RW,D,CON,LCL
4	$VARS	000252	85	RW,D,CON,LCL

ENTRY POINTS

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
COBEOF		1-000000												

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
BC	I*2	F-000010*	IDBUG	I*2	F-000004*	L	I*2	4-000250	NL	I*2	F-000006*			

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
A	R*3	4-000000	000250	84	(21)
HDR	L*1	F-000002*	000001	0	(1)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
600'	3-000062	601'	3-000000						

FUNCTIONS AND SUBROUTINES REFERENCED

ASC2FD PACK

TOTAL SPACE ALLOCATED = 001126 299

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
0001            SUBROUTINE COBCTL(QUAD,BLOCK,J)
0002             IMPLICIT INTEGER (A-Z)
0003            BYTE BLOCK(1),QUAD(1),COBB(24)
0004           REAL COB(6)
0005            EQUIVALENCE(COBB,COB)
0006            DATA COB/'0@0@','I!@@',',@@,',',13QU','AD00','1ROW'/
0007            DO 100 I=1,4
0008            COBB(14+I)=QUAD(I)
0009    100      CONTINUE
0010            CALL ASC2FD(COBB,1,24,BLOCK,J)
0011            RETURN
0012            END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	000150	52	RW,I,CON,LCL
2	$PDATA	000010	4	RW,D,CON,LCL
3	$IDATA	000040	16	RW,D,CON,LCL
4	$VARS	000032	13	RW,D,CON,LCL

ENTRY POINTS

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
COBCTL		1-000000												

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
I	I*2	4-000030	J	I*2	F-000006*									

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
BLOCK	L*1	F-000004*	000001	0	(1)
COB	R*4	4-000000	000030	12	(6)
COBB	L*1	4-000000	000030	12	(24)
QUAD	L*1	F-000002*	000001	0	(1)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
100	**								

FUNCTIONS AND SUBROUTINES REFERENCED

ASC2FD

TOTAL SPACE ALLOCATED = 000252 85

NO FPP INSTRUCTIONS GENERATED

```
0001            SUBROUTINE XLATE(A,M,J,B,N)
                C
                C    SUBROUTINE TO TRANSLATE THE EIGHT BIT CLUSTER NUMBERS INTO
                C    THE SIX BIT FIELD DATA SYBBOLS NEEDED FOR THE WALKOVER TAPE...
                C     ARGUMENTS.........
                C     A IS SOURCE BYTE ARRAY
                C   B  IS TARGET BYTE ARRAY
                C      J  IS THE NUMBER OF BYTESS TO CONVERT
                C
0002              IMPLICIT INTEGER (A-Z)
0003              BYTE A(1),B(1),SYMBOL(64)
0004             COMMON/CLASS/SYMBOL,IDBUG
0005             DO 100 K=1,J
0006             P=K-1+M
0007            Q=(K-1)*2+N
0008             IF(A(P) .GT. 0 .AND. A(P) .LE. 62) GO TO 101
0009              B(Q)=63
0010            B(Q+1)=63
0011             GO TO 100
0012    101      CONTINUE
0013            B(Q)=SYMBOL(A(P))
0014              B(Q+1)=SYMBOL(A(P))
0015    100      CONTINUE
0016             CALL ASC2FD(B,N,J,B,N)
0017              RETURN
0018             END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	000332	109	RW,I,CON,LCL
3	$IDATA	000040	16	RW,D,CON,LCL
4	$VARS	000006	3	RW,D,CON,LCL
5	$TEMPS	000002	1	RW,D,CON,LCL
6	CLASS	000102	33	RW,D,OVR,GBL

ENTRY POINTS

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
XLATE		1-000000												

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
IDBUG	I*2	6-000100	J	I*2	F-000006*	K	I*2	4-000000	M	I*2	F-000004*	N	I*2	F-000012*
P	I*2	4-000002	Q	I*2	4-000004									

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
A	L*1	F-000002*	000001	0	(1)
B	L*1	F-000010*	000001	0	(1)
SYMBOL	L*1	6-000000	000100	32	(64)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
100	1-000234	101	1-000170						

FUNCTIONS AND SUBROUTINES REFERENCED

ASC2FD

TOTAL SPACE ALLOCATED = 000504 162

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
0001              SUBROUTINE ASC2FD(A,I,J,B,K)
0002                IMPLICIT INTEGER (A-Z)
0003                BYTE A(1),B(1)
0004               BYTE ASC(64)
0005               DATA ASC/64,91,93,35,94,32,65,66,67,68,69,70,71,72,73,74,75,
                  & 76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,41,45,43,60,
                  & 61,62,38,36,42,40,37,58,63,33,44,92,48,49,50,51,52,53,54,55,
                  & 56,57,39,59,47,46,34,95/
0006               KK=K
0007               DO 101 M=1,J
0008               P=I-1+M
0009               DO 100 N=1,64
0010              IF(A(P) .NE. ASC(N)) GO TO 100
0011              B(KK)=N-1
0012               KK=KK+1
0013               GO TO 101
0014    100         CONTINUE
0015              B(KK)=44
0016                KK=KK+1
0017    101         CONTINUE
0018                 RETURN
0019                END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	000274	94	RW,I,CON,LCL
3	$IDATA	000024	10	RW,D,CON,LCL
4	$VARS	000110	36	RW,D,CON,LCL
5	$TEMPS	000002	1	RW,D,CON,LCL

ENTRY POINTS

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
ASC2FD		1-000000												

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
I	I*2	F-000004*	J	I*2	F-000006*	K	I*2	F-000012*	KK	I*2	4-000100	M	I*2	4-000102
N	I*2	4-000106	P	I*2	4-000104									

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
A	L*1	F-000002*	000001	0	(1)
ASC	L*1	4-000000	000100	32	(64)
B	L*1	F-000010*	000001	0	(1)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
100	1-000206	101	1-000250						

TOTAL SPACE ALLOCATED = 000432 141

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
0001            SUBROUTINE ROWNO(NO,B,J)
0002             IMPLICIT INTEGER (A-Z)
0003            BYTE B(1),BHOLD(4)
0004            ENCODE(4,100,BHOLD) NO
0005    100     FORMAT(I4)
0006            DO 200 I=1,4
0007            IF(BHOLD(I) .EQ. ' ') BHOLD(I)='0'
0008    200     CONTINUE
0009            CALL ASC2FD(BHOLD,2,3,B,J)
0010            RETURN
0011              END
```

PROGRAM SECTIONS

NUMBER	NAME	SIZE		ATTRIBUTES
1	$CODE1	000172	61	RW,I,CON,LCL
2	$PDATA	000010	4	RW,D,CON,LCL
3	$IDATA	000032	13	RW,D,CON,LCL
4	$VARS	000006	3	RW,D,CON,LCL

ENTRY POINTS

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
ROWNO		1-000000												

VARIABLES

NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS	NAME	TYPE	ADDRESS
I	I*2	4-000004	J	I*2	F-000006*	NO	I*2	F-000002*						

ARRAYS

NAME	TYPE	ADDRESS	SIZE		DIMENSIONS
B	L*1	F-000004*	000001	0	(1)
BHOLD	L*1	4-000000	000004	2	(4)

LABELS

LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS	LABEL	ADDRESS
100'	3-000000	200	**						

FUNCTIONS AND SUBROUTINES REFERENCED

ASC2FD

TOTAL SPACE ALLOCATED = 000242 81

NO FPP INSTRUCTIONS GENERATED

SJNF.FTN /TR:BLOCKS/WR

```
,CL:=SY0:[100,220]SJNF
```